



# PROCEEDINGS OF THE CTFS-AA INTERNATIONAL FIELD BIOLOGY COURSE 2005



## **KHAO CHONG, THAILAND**

15 June – 14 July 2005

Edited by Rhett D. Harrison

## Preface

The CTFS-AA International Field Biology Course is an annual, graduate-level field course in tropical forest biology run by the Center for Tropical Forest Science – Arnold Arboretum Asia Program (CTFS-AA; [www.ctfs-aa.org](http://www.ctfs-aa.org)) in collaboration with institutional partners in South and Southeast Asia. The CTFS-AA International Field Biology Course 2005 was held at Khao Chong Wildlife Extension and Conservation Center, Thailand from 15 June to 14 July and hosted by the National Parks, Wildlife and Plant Conservation Department, Thailand. It was the fifth such course organised by CTFS-AA. Last year's the course was held at Lambir Hills National Park, Sarawak and in 2001 and 2003 the courses were held at Pasoh Forest Reserve, Peninsular Malaysia. The next year's course will be announced soon.

The aim of these courses is to provide high level training in the biology of forests in South and Southeast Asia. The courses are aimed at upper-level undergraduate and graduate students from the region, who are at the start of their thesis research or professional careers in forest biology. During the course topics in forest biology are taught by a wide range of experts in tropical forest science. There is a strong emphasis on the development of independent research projects during the course. Students are also exposed to different ecosystem types, as well as forest related industries, through course excursions.

The CTFS-AA International Field Biology Course 2005 was attended by 21 students from nine countries (Malaysia, Thailand, Philippines, USA, Taiwan, China, Singapore, India, and Sri Lanka) and a total of 22 resource staff from a variety of national and international institutions gave lectures and practical instruction. The course in 2005 was implemented by Rhett Harrison (CTFS-AA), Sarayudh Bunyavejchewin (National Parks, Wildlife and Plant Conservation Department, Thailand), and Luan Keng Wang (Raffles Museum, Singapore). Due to their efforts the course proved to be a huge success. The following report illustrates the hard work of the organizers and the enthusiasm and commitment of the students. We look forward to another successful course in 2006.

Stuart J. Davies  
Director, Center for Tropical Forest Science

## **Acknowledgements**

The organisers of the CTFS-AA International Field Biology Course 2005 wish to thank all the resource staff who gave their time to teach on the course. Without the commitment of these researchers to see a graduate field biology course in the region succeed the course at Khao Chong could obviously not have taken place. In particular we would like to thank Ms Luan Keng Wang (Raffles Museum, Singapore) whose assistance made for a much smoother running of the course. We would also like to acknowledge the considerable help of our field assistants, especially Mr Pitoon Kongnoo and Mr Precha Putarak. A list of all the resource staff who contributed to the course appears at the end of these proceedings.

We would like to thank our guest speakers at the Opening Ceremony, Mr Surapon Wichaidit, Deputy Governor Trang Province, Dr Wichien Sumantakun, Acting Director of Research, National Parks, Wildlife and Plant Conservation Department, Thailand, and Dr Stuart Davies, Director, Center for Tropical Forest Science for giving their time to come and speak to the participants.

The organisers would also like to acknowledge the assistance of the staff at Khao Chong in particular Mr Suthum Sudthavaspong, Director of the Khao Chong Wildlife Extension and Conservation Center, and his staff for the use of the center's facilities and for organising the catering, and Mr. Thawat Tingnga, Director of the Peninsular Botanic Gardens Khao Chong.

We would like to thank the staff at the Kantang Mangrove Research Station for accommodating our excursions to the mangroves. Our trip to the para-rubber plantation was made possible through the assistance of Mr Precha Putarak. The staff at PlanToys rubberwood factory gave us a very informative tour of their facilities, while Dr Voradol Chamchumroon, Director of the Thung Khai Peninsular Botanic Gardens, personally escorted us around his gardens. The organisers would like to thank all the above and their staff for hosting the course.

Our extended field trip to Chiang Mai was made possible through the assistance of our hosts the National Park, Wildlife and Plant Conservation Department. We would especially like to thank Mr Praphoch Manusaran, Director Doi Inthanon National Park and Dr Pratheep Rojanadirok, Director Doi Chiang Dao Wildlife Sanctuary for hosting our excursions to their respective stations, and to the public relations staff at the Doi Inthanon Royal Project for the informative tour they gave us.

Financial support for the field course came from the Center for Tropical Forest Science – Arnold Arboretum Asia Program of the Smithsonian Tropical Research Institute and the Arnold Arboretum of Harvard University. Tunghai University very generously provided funds to purchase a set of field equipment for the course, through a grant to Dr I Fang Sun, and funded the flights of the Taiwanese participants and Dr Sun. Dr D. W. Roubik funded his flights through other sources. We would like to acknowledge their contribution to the field course in this respect. In addition to hosting the course the National Parks, Wildlife and Plant Conservation Department, Thailand covered the costs of their employees and facilitated the course in various other ways for which we are very grateful.

Thanks to all.  
The organizers,

Rhett Harrison (Center for Tropical Forest Science – Arnold Arboretum)  
Sarayudh Bunyavejchewin (National Parks, Wildlife and Plant Conservation Department, Thailand)

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## Field course program

### Overview

15 June		Arrival at Trang Airport Registration at Khao Chong
16 June	09:00 10:00 – 12:00 14:00 – 18:00	Opening ceremony Orientation to Khao Chong Lectures start
16 – 25 June		Lectures and practicals Group projects
20 June		Field trip to Kantang (mangrove flora)
23 June	09:00 14:00	Excursion to rubber plantation & PlanToys® factory Excursion to Botanic Gardens
26 – 30 June		Field trip to Chiang Mai
30 June		Submission of group project reports
1 July – 8 July		Lectures and practicals
5 July		Field trip to Kantang (mangrove fauna)
8 July		Submission of excursion reports
8 – 11 July		Independent student projects
12 July		Data analyses and write-up
12 July		Submission of independent project reports
13 July		Presentations of group and independent student projects. Farewell party.
14 July		Depart Trang Airport

## Open ceremony speeches

### Official Opening

Mr Surapon Wichaidit

Deputy Governor, Trang Province, Thailand

First I would like to welcome all the participants of the Center for Tropical Forest Science – Arnold Arboretum international field biology course to Thailand and, of course, specifically to Trang.

I also would like to thank the organisers, in particular the National Parks, Wildlife and Plant Conservation Department and the officials of the Khao Chong Peninsular Botanic Garden, Khao Chong Wildlife Extension and Conservation Center and Khao Ban Thad Sanctuary for their efforts in preparing for this course. And I would like to thank the Center for Tropical Forest Science for choosing to hold this course in Khao Chong, and thus giving us the opportunity of hosting so many international guests.

I am privileged to be invited here to officiate over the opening of this field course.

I really cannot overstate the value of international courses of this type. Despite the political barriers that, unfortunately, often exist, the SE Asian countries have many benefits to derive from exchanging and sharing experiences. First, with respect to the forests you are here to study, obviously environments throughout the region have much in common. We share similar rain forests, similar and with Malaysia contiguous montane forests, similar mangroves, not to mention our coral reefs and marine ecosystems. It is also true that we share many of the same problems with respect to the management and development of our natural resources. Unfortunately, in the race towards economic development the value placed on natural resources often vastly underestimates their real value in products and services, such as the supply of clean water, climate amelioration or aesthetic value. How much is a hornbill or a beautiful waterfall, as we have here at Khao Chong, worth to Thailand? Unfortunately, the value of these resources is often only recognised after they have been lost.

It is the responsibility of government to promote economic growth. However, how do we achieve growth without mining our resources or damaging our future economic security through environmental deterioration? These are global issues, but they must be resolved at a local level. Mismanagement of resources leads ultimately to lost economic potential.

I know that during this course you will be learning many things about forest ecology. Some aspects have immediate relevance to how we manage forest and other natural resources. Others are more indirect but are nevertheless important for our overall appreciation and therefore evaluation of this resource. This course offers a rare opportunity for students of these environments to come together, to learn together and to share experiences and lessons about the rich natural environments we have here in SE Asia. I encourage you to make the most of this opportunity and to take home with you not only a greater appreciation of these natural resources but also a sense of the shared responsibility.

I sincerely hope that you enjoy your stay here in Khao Chong, Trang and best of luck with your course.

**Welcome address**

**Mr Wichien Sumantakun**

**Acting Director Forest Research Office,**

**National Parks, Wildlife and Plant Conservation Department, Thailand**

It has fallen to me, on behalf of the National Parks, Wildlife and Plant Conservation Department Thailand, to welcome both the participants and resource staff to Khao Chong and specifically to the Center for Tropical Forest Science – Arnold Arboretum Asia Program International Field Biology Course 2005. For the international participants I also know that this will be the first visit to Thailand for most of you. Welcome to the Land of Smiles.

The name of our department, the “National Parks, Wildlife and Plant Conservation Department” is quite new – having been born out of a re-organisation of the former Royal Forest Department, which might lead you into thinking our relationship with the Center for Tropical Forest Science – Arnold Arboretum Asia Program is also rather new. In fact the opposite is true. The CTFS-AA plot at Huai Kha Kheng was established in 1993, largely through the efforts of Dr Sarayudh Bunyavejchewin, Dr Jim LaFrankie, and Dr Peter Ashton, making it the third site in the CTFS-AA network. That site has recently completed its 3<sup>rd</sup> census and we are looking forward to the publication of the stand-book soon. More recently in 1998, Khao Chong was added to the network and as you will later see is already on to its second census. Khao Chong plugs an important gap in the CTFS-AA network. As many of you are aware the CTFS-AA program now has sites along a latitudinal and seasonality gradient that runs from Lambir Hills in Sarawak Malaysia, which is 3 degrees N and is aseasonal, to Bukit Timah in Singapore, to Pasoh in Peninsular Malaysia, to here at Khao Chong and on to Huai Kha Kheng at 15 degrees N and with a pronounced 6 month dry season. This series of sites, where at each site the same protocol of measuring every tree down to 1cm diameter has been followed, encompasses a diversity gradient running from over 1200 trees species in a 52 ha plot at Lambir Hills to 251 species in 50 ha at Huai Kha Khang. With over 600 species in 24 ha Khao Chong is remarkably diverse given its degree of seasonality and lies at a critical point floristically in the transition from the moist ever-wet forests further south in the peninsular to the more seasonal forests north of here. I think you will also find that is a remarkably beautiful forest and I hope in your busy schedule ahead that you take some time to appreciate its aesthetic qualities.

The value of the CTFS-AA program is clearly in the collaboration. The value both to science and to applied fields, such as natural resource management or conservation biology, of a series of sites representative of all the main floristic elements in the Asian region is obviously far more than the sum of each of the separate plots. This field course, which I understand is organised annually by CTFS-AA, is one element of that collaboration and I am very pleased that we at the National Parks, Wildlife and Plant Conservation Department Thailand have the opportunity to host this course in 2005.

Just looking at the program, I can see that this course is a great opportunity for the participants. Over the coming month you will be studying many different aspects of forest ecology from teachers who are experts in their field. You are visiting several other sites both around Khao Chong and also in the north when you travel to Chiang Mai. And you also have a great opportunity to benefit from the cultural experience. Fully nine countries are represented among the participants and even more if you include all the resource staff. I hope that you make the most of these opportunities.

I would like to finish with just a few acknowledgements. Firstly to CTFS-AA and in particular Dr Stuart Davies, Scientific Director of the Asia Program for running this course at Khao Chong and Dr Rhett Harrison the course organiser. I would like to acknowledge the hard work of Dr Sarayudh Bunyavejchewin and the staff of the Peninsular Botanic Gardens Khao Chong, Khao Chong Wildlife Extension and Conservation Center and the Khao Ban Thad Sanctuary for their efforts in preparing for this course.

## Lecture Course

### 15 – 25 June: Introduction to Tropical Forest Flora and Fauna

16 June	09:00			Opening ceremony
	10:30	Dr S. Davies	Lecture	Introduction to CTFS-AA
	14:00	Dr. S. Bunyavejchewin	Field practical	Introduction to 24 ha plot
	19:30	Dr. S. Bunyavejchewin	Lecture	Forests of Thailand
17 June	08:00	Dr J. V. LaFrankie	Field practical	Plant identification
	19:30	Dr J. V. LaFrankie	Lecture	Trees of tropical Asia database
18 June	08:00	Dr J. V. LaFrankie	Field practical	Plant identification
	19:30	Students	Talks	Research topics (10 mins)
19 June	08:00	Dr J. V. LaFrankie	Lecture	Plant identification: Review
	14:00	Dr. S. Bunyavejchewin	Field practical	Establishing a tree census plot
	19:30	Students	Talks	Research topics (10 mins)
20 June	All day	Dr. S. Bunyavejchewin	Excursion	Kantang Mangroves
	18:30	Dr D. Roubik	Lecture	Insects
	19:30	Dr D. Lohman	Lecture	Ants
21 June	08:00	Dr D. Roubik et al.	Field practical	Insect trapping methods
	14:00	Dr G. Gale / Dr N. Bhumpakphan	Field practical	Vertebrate sampling methods
	19:30	Dr G. Gale	Lecture	Birds
	20:30	Dr V. Chimchome	Lecture	Hornbills
22 June	06:00	Dr G. Gale / Dr N. Bhumpakphan	Field practical	Vertebrate sampling methods
	10:00	Dr D. Roubik	Field practical	Insect identification
	19:30	Dr N. Bhumpakphan	Lecture	Mammals
	20:30	Ms K. Muangkhum	Lecture	Gibbons
23 June	08:00		Excursion	Rubber plantation / Playtoys®
	14:00		Excursion	Peninsular Botanic Gardens
	19:00	Mr Tanya Chan-ard	Field practical	Amphibians and reptiles
24 June	08:00	Mr Tanya Chan-ard	Lecture	Amphibians and reptiles
	09:00	Mr Tanya Chan-ard	Field practical	Amphibians and reptiles
	14:00	Dr I Fang Sun		Twenty questions
	19:30	Students		Proposals for group projects
25 June	08:00	Dr I Fang Sun		Group projects
	19:30	Dr I Fang Sun		Analysis of group projects

**26 – 30 June: Chang Mai excursion**

26 June	05:30	Dr S. Bunyavejchewin	Excursion	Travel to Doi Inthanon
	18:00	National park staff	Lecture	Introduction to Doi Inthanon
27 June	08:00	Dr K. Sringeurnyung	Excursion	Doi Inthanon
	16:00			Royal Project Doi Inthanon
	18:00			Return to Chiang Mai
28 June	08:00	Dr S. Bunyavejchewin	Excursion	Visit Doi Sutep
	14:00		Excursion	Elephant trekking centre
	17:00			Transfer to Hotel Doi Chiang Dao
29 June	All day	Dr. P. Rojanadirok	Excursion	Visit Doi Chiang Dao
	17:00			Return to Chiang Mai
30 June	09:00		Excursion	Visit Woodcarving center
	13:00			Return to Khao Chong

**1 July – 7 July: Forest Ecology**

1 July	08:00	Dr R. Corlett	Lecture	Basic statistics
	10:00	Dr R. Corlett	Practical exercise	Basic statistics
	19:30	Dr R. Corlett	Lecture	Comparison of tropical forests
2 July	08:00	Dr R. Corlett	Lecture	Frugivory & seed dispersal
	10:00	Dr R. Corlett	Practical exercise	Frugivory & seed dispersal
	19:30	Dr D. Roubik	Lecture	Pollination
3 July	08:00	Dr I Fang Sun	Lecture	Plant population ecology
	10:00	Dr I Fang Sun	Practical exercise	Plant population ecology
	19:30	Dr R. D. Harrison	Lecture	Fig diversity
4 July	08:00	Dr D. Roubik	Lecture	Tropical bees
	10:00	Dr D. Roubik	Practical exercise	Tropical bees
	19:30	Dr P. Tantichodok	Lecture	Tropical brackish-water ecosystems
5 July	All day	Mr N. Sivasothi	Excursion	Kantang
	19:30	Mr N. Sivasothi	Lecture	Conservation Biology
	20:30	Dr S Lum	Lecture	Molecular ecology
6 July	08:00	Dr R. D. Harrison	Lecture	Fig biology
	10:00	Dr R. D. Harrison	Practical exercise	Fig biology
	19:30	Students	Lecture	Proposals for student projects
7 July	08:00	Dr D. Lohman	Lecture	Ant ecology
	10:00	Dr D. Lohman	Practical exercise	Ant ecology
	19:30	Students		Proposals for student projects

## Abstracts

### **An introduction to CTFS-AA**

**Stuart Davies**

**CTFS-AA, Arnold Arboretum**

The Center for Tropical Forest Science of the Smithsonian Tropical Research Institute is a global initiative in long-term tropical forest research. The broad objectives of this research program are (1) to develop a general theory of tropical forest diversity and dynamics, providing explanations of the relative importance of biotic and abiotic factors in controlling species distributions and the regulation of population and community dynamics, and (2) to develop models incorporating ecological and economic analyses for predicting human impacts on and optimizing sustainable utilization of tropical forests. These and many other fundamental ecological questions concerning tropical forests are best addressed by a comparative approach involving long-term, individual-based, mapped, permanent forest plots. The consortium of researchers and institutions collaborating within CTFS has established a pan-tropical network of 17 large-scale (50 ha) permanent plots in 14 countries representing the diversity of tropical forests.

The CTFS-Arnold Arboretum Asia Program includes eight core sites, each with a large-scale research plot. The sites were chosen to represent the major biogeographical areas of South and Southeast Asia. The plots are found across a gradient of climates, soil types, and natural disturbance regimes. Current CTFS-AA core sites are in Malaysia, Thailand, India, Sri Lanka, Philippines and Singapore. CTFS-AA also collaborates with associated sites in Taiwan and Thailand. In this talk, I discuss the comparative ecology of the forests in which the eight plots have been established. A wide range of research is now being conducted within the CTFS plots. An overview of these studies is provided in this talk.

### **Forests of Thailand**

**Sarayudh Bunyavejchewin**

**National Parks, Wildlife and Plant Conservation Department, Thailand**

Thailand is a country with diverse forest types. Thai forests are classified into two basic categories, evergreen and deciduous. Based on structure, floristics, and abiotic environment, evergreen forests have been further classified into six forest types; seasonal moist evergreen forest, seasonal dry evergreen forest, lower montane forest, upper montane forest, pine forest, mangrove forest, and peat swamp forest. Deciduous forests consist of two types, dry deciduous dipterocarp forest and dry mixed deciduous forest. And there is one forest type intermediate between evergreen and deciduous described as semi-deciduous forest. I will briefly describe the structure, floristics and environmental factors of each of these forest types.

Bunyavejchewin, S. 1999. Structure and dynamics in seasonal dry evergreen forest in northeastern Thailand. *Journal of Vegetation Science* 10 : 787-792.

### **Field practical on tree identification**

**Jim LaFrankie**

**CTFS-AA, Philippines**

Over three days students will go with the course leaders and tree climbers to the 24-ha plot to collect leaf and twig specimens for 30 species of tree representing some 20 families and genera. In the course of their collecting students will make notes on field characters of color, sap, bark, twig and leaf features. Students will keep and study their leaf collections for the duration of the course.

### **The CTFS-AA Trees of Tropical Asia database**

**Jim LaFrankie**

**CTFS-AA, Philippines**

The lecture presents a brief introduction to the database compiled through the CTFS-AA network of long-term ecological research plots. The database includes taxonomic and ecological information on thousands of species of trees. It also includes photographs and meta-data from the permanent plots such as tables and distribution maps. The database is organized in FileMaker Pro software which will be explained and demonstrated. This software is well-suited for individual record keeping as well as institutional projects. While the CTFS-AA database is still in its infancy, it is now growing rapidly and should within a year be a useful on-line tool for ecological research and reference.

### **Establishing a tree census plot**

**Sarayudh Bunyavejchewin**

**National Parks, Wildlife and Plant Conservation Department, Thailand**

Design, intensity, and size of plot to be established are dependent on objectives and budget of a study. Most plots follow a basic common design for the convenience of inter-site comparisons. However, a design can be modified if the adopted-design can produce useful and representative results.

### **Insects**

**David Roubik**

**Smithsonian Tropical Research Institute, Panama**

We share the world with insects. They are mostly neither friends nor enemies, although the media, including scientific literature, often depict them as our great enemies or forgotten mutualists. They are neither. Their legions are several million strong, and those species are adapted to seemingly strange or novel life habits, most of which have nothing whatsoever to do with humans. However, they do bear a large imprint on the plant, fungal and animal worlds in general and, fortunately for scientists, they are often closely adapted to our analogues- visually-oriented, vertebrate predators and omnivores. We read and learn about them because it serves us, and it almost always has.

Most insects are tropical, and most have a life cycle that includes an egg, serial immature stages, a pupa, and an adult. These have their respective biologies. By biology, I mean natural enemies (predators and parasites), competitors, food resources, tight and loose evolutionary relationships, genealogical and biogeographical histories, constraints and adaptations, and multifaceted ecological niches (what they do and require, and what does what to them). We will read about, observe and discuss 1) biogeography and systematics, 2) physiology, ecology and behavior, 3) genetics and evolution, 4) natural history and applied entomology, 5) medical entomology, and 6) diverse topics on 'how to be an insect connoisseur'.

### **Ants**

**David Lohman**

**Harvard University, USA**

Ants are among the most abundant and recognizable animals on the planet. As of May 12<sup>th</sup>, 2005, there are 11,832 described species, and this figure is thought to be much smaller than the actual number of ant species. By comparison, there are around 9,800 described species of birds in the world. Ants play important roles in litter decomposition, aeration of forest soils, and as symbiotic partners to many plants and other insects. All ant species are haplodiploid—a genetic system in which females have two sets of chromosomes and males have one. This creates an evolutionary situation where it is more advantageous for ant females to produce sisters than to

reproduce themselves. Haplodiploidy favors a division of labor in which only a few females reproduce and the rest help raise their sisters. All ant workers are female—males are usually only produced during particular times of the year—and workers within a single colony may have specialized bodies and social roles called “castes”. We will scratch the surface of myrmecology by examining basic anatomy, life cycle, social structure, and habits of ants. We will also examine some of the more unusual and evolutionarily derived ant lifestyles: slave-making ants, fungus gardening ants, and weaver ants.

## **Appendix: Internet Resources for Ant Research**

### Web sites

Searchable database of all ant literature ever published

<http://cmave.usda.ufl.edu/~formis/downloads.html>

Searchable database of downloadable ant literature pdfs

[http://iris.biosci.ohio-state.edu/hymenoptera/hym\\_db\\_form.html](http://iris.biosci.ohio-state.edu/hymenoptera/hym_db_form.html)

Ant taxonomy and photographs

<http://www.myrmecos.net/>

<http://antweb.org/>

<http://www.antbase.org/>

<http://www.antbase.de/> (Borneo)

<http://ant.edb.miyakyo-u.ac.jp/E/index.html> (Japan)

Harvard ant type specimen photographs

<http://mcz-28168.oeb.harvard.edu/mcztypedb.htm>

Ant photographic keys, distribution maps, and checklists

<http://www.discoverlife.org/nh/tx/Insecta/Hymenoptera/Formicidae/> (Philippines, Indonesia, Micronesia, *et al.*)

<http://homepage.mac.com/aenictus/AntsofBorneo.htm> (Borneo)

Professional Societies for ant research

*IUSSI- International Union for the Study of Social Insects*

<http://www.iussi.org/>

*ANeT-International Network for the Study of Asian Ants*

[http://www.geocities.com/anet\\_diwpa/](http://www.geocities.com/anet_diwpa/)

Journals devoted to ants and other social insects

*Insectes Sociaux*

<http://www.kuleuven.ac.be/bio/ento/inssoc.htm>

*Sociobiology*

<http://www.csuchico.edu/biol/Sociobiology/sociobiologyindex.html>

General Insect Equipment and books

*Bioquip-probably the largest insect equipment supplier in the world*

<http://www.bioquip.com/>

*Australian Entomological Supplies-good selection, and inexpensive shipping to Asia*

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<http://www.entosupplies.com.au/>

*Bauer & Sato Japan—huge selection of books, many of which are not available outside Japan. The owner is fluent in English, so write an email if you can't navigate the Japanese website.*

<http://www.insectbook.com/>

*China Scientific Book Services—many books with English summaries of the Chinese fauna. If you can go to their store in Beijing, the prices are 1/10<sup>th</sup> as much as the web site prices.*

<http://www.hceis.com/class.asp?aid=31&nid=273>

Insect artificial diet supplies

*Bio-Serv-sells salt and vitamin mixtures required for Bhatkar diet*

<http://www.insectrearing.com/>

The Ant Course

[http://www.calacademy.org/research/entomology/ant\\_course/](http://www.calacademy.org/research/entomology/ant_course/)

Research Aids

*Sources of Fluon®*

<http://www.kellysearch.co.uk/gb-company-2027666.html>

<http://www.bioquip.com/>(sold as Insect-a-slip)

*Sources of Tanglefoot (Tangle-trap adhesive)*

<http://www.bioquip.com/>

<http://www.tanglefoot.com/>

Conservation International Ant Monitoring Protocol

[http://www.teaminitiative.org/application/resources/pdf/ant\\_3\\_12\\_03.pdf](http://www.teaminitiative.org/application/resources/pdf/ant_3_12_03.pdf)

Bhatkar Diet Recipe

Bhatkar, A. P., and W. H. Whitcomb. 1970. Artificial diet for rearing various species of ants. *Florida Entomologist* 53: 229–232.

This diet will sustain almost any ant species in the lab indefinitely. Ants should be fed Bhatkar diet every day or every other day, and given a dead insect every week to supplement this diet. Bhatkar diet can be made in large batches and stored in a freezer.

1 egg, 62 ml honey, 1 g vitamins, 1 g minerals and salts, 5 g agar, 500 ml water

Dissolve the agar in 250 ml boiling water. Let it cool. With an egg beater, mix 250 ml water, honey, vitamins, minerals, and the egg until smooth. Add to this mixture, stirring constantly, to the agar solution. Pour into petri dishes (0.5-1 cm deep) to set. Store in the refrigerator. The recipe fills four 15-cm diameter petri dishes, and is jellylike in consistency.

### ***Insect sampling methods***

**David Roubik**

**Smithsonian Tropical Research Institute**

Each trapping method has its advantages, disadvantages and biases in terms of the insect groups predominantly sampled. Therefore, any assessment of captures must be made in the context of the environment and trapping method employed. We will use a variety of trapping methods including light traps, Malaise traps, pit fall traps, litter samples, and butterfly bait traps to sample the same habitat and then discuss the relative merits and biases of each method.

## **Vertebrate sampling methods**

**George Gale**

**King Mongkut's University of Technology, Thailand**

We will focus on two basic methods of sampling birds, distance sampling (which can be used for a wide variety of organisms) and ringing/mist netting (suitable for bats as well).

If a researcher is interested in comparing abundance among species, habitats, or sites, or in finding trends in population size, then it is important to use methods that are consistent over time and space, and therefore one needs some measure of the probability of detection. Distance sampling, an extension of plot sampling, is one of several methods which can be used to estimate the detectability. In addition, distance sampling is preferable to conventional strip transects because it does not assume perfect detection of all target organisms and specifically estimates the number of target organisms not detected. Currently, the program DISTANCE, available free from the Web, is the primary tool used for designing and analyzing distance sampling surveys. Distance sampling has been successfully used to study hundreds of species from birds to plants. However, it is not suited for extremely rare species nor does it tell us why populations are increasing or declining.

Ringing (known as banding in North America), the process of capturing and uniquely marking birds, is a technique that while capable of estimating population abundance, is better suited for estimating questions related to vital rates of populations, particularly survival and reproduction. In addition to mark-recapture techniques to estimate abundance, unique color ring combinations can be used for mark-resight studies whereby uniquely marked individuals can be observed in the field to delimit home ranges, dispersal, breeding and feeding behavior, as well as basic body condition. However, in forest systems in particular, ringing is generally limited to those species that can be captured in the lower canopy.

We will provide brief examples using both techniques from our research in Khao Yai National Park (Northeastern Thailand).

Keyes, B. E. and Grue, C. E. (1982). Capturing birds with mist nets: A review. *North American Bird Bander* 7, 2-14.

Rosenstock, S. S., Anderson, K.M., Giesen, T., Leukering and Carter, M.F. (2001). Landbird counting techniques: current practices and an alternative. *The Auk*. 119, 46-53.

Silkey, M., Nur, N. and Geupel, G. R. (1999). The use of mist-net capture rates to monitor annual variation in abundance: a validation study. *The Condor* 101, 288-298.

Stoate C., R. Borralho and M. Araújo (1997). Factors affecting corn bunting *Miliaria calandra* abundance in a Portuguese agricultural landscape. *Agriculture, Ecosystems and Environment*. 77, 219–226.

Thompson, W. L. (2002). Towards reliable bird surveys: accounting for individuals present but not detected. *The Auk* 119, 18–25.

## **Birds**

**George Gale**

**King Mongkut's University of Technology, Thailand**

Many of the basic principles of ecology and evolution have been developed from the study of birds primarily because they are relatively easy to observe compared to other groups of organisms. Birds arose from a group of meat-eating theropod dinosaurs approximately 130 million years ago, while representatives of most living orders appeared in the Paleocene, Eocene and Oligocene 65 to 22 million years ago. Currently classified into 23 orders, and 141 families, there are  $\pm 10,000$  species of extant birds. Of the birds, the largest order is the Passeriformes (typical songbirds/perching birds) with 5,700 species. Of the non-passerine

Ciconiiformes are the largest and most diverse order, (1027 species) including storks, birds of prey, most seabirds and waders.

In general, a bird's bill can also tell us much about ecology and evolution, and has provided some of the best examples of natural selection and adaptive radiation (e.g. Galapagos finches).

Southeast Asia encompasses several zoogeographic regions and is particularly species rich in birds. For example, Thailand has 978 species and encompasses 5 faunal regions. The main families of Thailand and the region will be discussed.

Barbosa, A. and E. Moreno 1999. Evolution of foraging strategies in shorebirds: an ecomorphological approach. *Auk*: 116: 712-725.

Dial, K.P. 2003. Wing-assisted incline running and the evolution of flight. *Science* 299: 402-404.

Gaither, J. C. 1994. Understory avifauna of a Bornean peat swamp forest: is it depauperate? *Wilson Bulletin*: 106: 381-390.

Grant, P. R. and P. T. Boag 1980. Rainfall on the Galapagos and the demography of Darwin's finches. *Auk*: 97: 227-244.

Karr, J. R. 1980. Geographical variation in the avifaunas of tropical forest undergrowth. *Auk*: 97: 283-298.

### **Hornbills**

#### **Viajak Chimchome**

#### **Kasetsart University, Thailand**

Hornbills are omnivorous, but their main food consists of fruit. At Khao Yai National Park hornbills consume at least 70 species of animals and 84 species (57 genera, 30 families) of plant fruits during their life cycle (namely early nesting, nesting, late nesting and flocking periods). Through their habit of storing many fruits each time they feed and regurgitating as they move, hornbills are undoubtedly good seed dispersers. Not only do they consume large amounts of fruit but hornbills also move over large ranges (4-35 km<sup>2</sup> depending on species), thus enhance long-distance seed dispersion. Breeding success in hornbills is influenced by the availability of suitable nest cavities. Besides natural causes, human activities particularly poaching obviously affect the breeding success of hornbills. Participation in the research and conservation program by villagers and urban people in Budo-Sungai Padi National Park, south Thailand was considered successful after the almost total eradication of poaching. Deforestation continues to be the biggest threat to the conservation of hornbills in Thailand and other tropical countries. Deforestation is a direct result of increased human population and developmental demands.

### **Gibbons**

#### **Kullatida Muangkhum**

#### **Thailand Institute of Scientific and Technological Research**

Gibbons, the lesser ape (Order Primates, family Pongidae), are arboreal, frugivorous, live in territorial family groups, and are limited to the forests of Southeast Asia. Twelve species are known, of which four are found in Thailand. They are physically adapted to an arboreal life style; their diet of fruit means they play an important role as seed dispersers in the forest. Today they are encountering the same threatening factors as many other living species; primarily habitat destruction and illegal hunting. Study should lead us to understand how to manage natural resources to share with another species.

In this lecture I will discuss on the physical characteristics, distribution, behaviour, habitat and the status of gibbons. I will also present some of my own studies on the white-handed gibbon in Huai Kha Khaeng Wildlife Sanctuary.

- Carpenter, C. R. 1940. Field study in Siam of the behavior and social relations of the gibbon (*Hylobates lar*). *Comparative Psychology Monographs*. 16(5):1-122.
- Brockelman, W. Y. 1975. Gibbon populations and their conservation in Thailand. *Nat. Hist. Bull. Siam Soc.* 26(2): 133-157.
- Chivers, D.J. 1974. The siamang in Malaya ñ A field study of a primate in tropical rain forest (Contributions to primatology vol. 4). Karger: Basel and New York.
- Grzimek, B. 1990. Grzimek's Encyclopedia of Mammal. Vol. 2. McGraw-Hill Publishing Comp., New York. 648 p.

### **Herpetological studies**

**Tanya Chan-ard**

**National Science Museum, Thailand**

Amphibians are divided into three groups or orders: Urodeles (newts and salamanders), Gymnophionans (caecilians), and Anurans (frogs and toads). Some of the major differences that separate them from the other vertebrates include, a body covered with generally thin and moist skin, lack of protective outer layer such as scales, feathers or hairs; soft toes with no claws; a two-chambered heart in the larval stage and a three-chambered heart in adults; external fertilization of eggs; and the process of metamorphosis.

Reptiles are divided into four orders: Testudines (turtles and tortoises), Crocodylia (crocodiles, alligators, and gavials), Rhyncocephala (tuataaraas) and Squamata (lizards, amphisbaenians, and snakes). The reptile anatomy is more advanced than the amphibian's. It has a body covered by waterproof skin with scales or osteoderms (bony skin plates), lack of skin glands; toes with claws; three-chambered heart in adults (four-chambered for crocodilians); internal fertilization, oviparity (egg laying) and viviparity (live-bearing).

Reptiles and amphibians are highly diverse in Thailand. There are 140 species of amphibians and 350 species of reptiles in the region, but many are under considerable threat. Many species are important to the ecology of their habitats, acting as both prey and predators, and a decline in numbers of them maybe a sign of environmental pollution, habitat lost, or hunting.

Inventory and monitoring techniques for reptiles and amphibians are needed for the rapid surveys. I propose to demonstrate general collecting, visual encounter surveys (VES) and systematic sampling surveys (SSS). General collecting is used to investigate species richness in various habitats and methods such as sighting, listening, and sign collecting are employed. In SSS the target is to record 100 specimens for each habitat type. This technique is useful for the comparison of species richness between habitats. And VES is used to survey species richness and relative abundant in a constant period of time. Details of these techniques will be explained further in the full lecture and field practice.

### **Twenty questions**

**I Fang Sun**

**Tunghai University, Taiwan**

This is an exercise in developing scientific thinking. Participants will go into the forest with instructions to think of 20 questions. Then working in groups the participants will discuss each of the questions and gradually focusing on more interesting ones. Finally, selecting one question each group will develop hypotheses to test the idea in a one-day group project.

**Long-term ecological studies on Doi Inthanon**  
**Kriangsak Sringueunyung**  
**Mae Joe University, Thailand**

The 15 ha Doi Inthanon Forest Dynamics Plot was established in 1996 by five universities, one museum and one government section in a lower montane forest ( 1700 m altitude) on Doi Inthanon (Doi Inthanon National Park, National Park Wildlife and Plant Conservation Department, Chiang Mai Province Northern Thailand). The first census of the was completed in March 2000 and identification was completed in March 2001. The forest canopy is dense. The tallest tree in the plot and the maximum tree dbh are 50 m and 175 cm dbh, respectively. Aboveground biomass is estimated to be 570 tons/ha. Fagaceae and Lauraceae are the dominant families in term of basal area in the plot.

**Doi Sutep**  
**Sarayudh Bunyavejchewin**

**National Parks, Wildlife and Plant Conservation Department, Thailand**

Doi Suthep-Pui National Park is located between 18° 43' N-19° 08' N and 98° 45' E-98° 58' E, approximately 5 km west of the city of Chiang Mai in the north of Thailand. It consists of two separate components with total area of about 262.5 sq. km. The forested area comprises approximately 60% evenly divided (about 20% each) between three major forest types; *hill evergreen forest*, *mixed deciduous forest*, and *dry dipterocarp forest*.

The general topography of the entire area is rugged mountains with elevations ranging from 350 m to 1,685 m. The two highest peaks are Doi Pui and Doi Suthep with 1,685 m and 1,130 m, respectively. From these two peaks originate several major rivers and streams which are important water sources providing year-round supply to the northern region.

The geological structure of this area was classified as Northwest Continental Highland consisting of a mixture of muscovite, biotite, gneiss, mica-schist, feldspar from Tertiary and Triassic age. The soil characteristics differ among major forest types. The soils in the evergreen forest, which normally occur at higher elevation and have higher humidity, are classified as rich well-drained sandy loams, with a high organic content and deep mineral layer, and are subject to erosion. On the other hand, the soils in deciduous forests, especially in dry dipterocarp forest which normally occurs in the lower range of elevations, are highly compacted and poorly drained lateritic soils, low in fertility and organic matter content.

From climatic records (1980-1996) the average minimum temperature is 12°C (January), and average maximum temperature is 25 °C (April). Rain occurs throughout the year. The monthly average rainfall ranges from 2.14 mm in February to 400.45 mm in September with an average annual rainfall of 2043 mm. The average relative humidity ranges from 58% in March to 89% in September.

Long before the establishment of the national park, this area was disturbed, mainly by hill-tribe people practicing shifting cultivation (40% total area). However, most of the disturbed areas were in the high elevations. Recently, human disturbance has been reduced through various programs initiated by different institutions, including government institutions, non-government organizations, and the local communities. Some of this area is being restored, but the rest consists of residential areas.

**Doi Chiang Dao**  
**Pratheep Rojanadirok**

**National Parks, Wildlife and Plant Conservation Department, Thailand**

The peak of Doi Chiang Dao is limestone. The special conditions of the limestone substrate (high pH, low water availability) make the forests at this altitude on Doi Chiang Doi very different

from those found on nearby Doi Inthanon. Also, because it is montane the forests are very different from other lowland limestone areas. We will start walking through forest composed of patches of pine and lower montane mossy forest, before emerging on to areas of grassland with shrubs. Starting from the Doi Chiang Dao Hotel we will take pick-ups up the mountain for approximately 2 hours, before walking into the forest for approximately 6 hours. There we will look at the forest structure and botany before returning. The whole trip will take 8-9 hours.

### **Statistics**

**Richard T. Corlett,  
University of Hong Kong, China**

The availability of user-friendly statistical packages has made statistics too easy: it is no longer necessary to know what you are doing or why. One aim of this session, therefore, is to make the statistical analysis of ecological data as difficult as it should be, by making you aware of issues that the packages don't always mention. I will also illustrate the range of statistical techniques available for the analysis of standard ecological datasets. The topics covered will probably include: hypotheses and null hypotheses; differences and trends; statistical significance; significance tests; data types; parametric and nonparametric tests; one-tailed and two-tailed tests; testing for differences; testing for trends; confounding effects; observations vs. experiments; non-independence and pseudo-replication.

### **Comparison among tropical forests: five rainforests**

**Richard T. Corlett  
University of Hong Kong, China**

Tropical forests are variable on all spatial scales, but I will concentrate on the broadest – biogeographical regions – and consider only lowland evergreen rainforests. There are five major rainforest regions: the Neotropics (S. & C. America); Africa (C. & W. Africa); Asia (SE Asia and various outliers); New Guinea (and Australia); and Madagascar. Rainforests in these five regions are similar because the laws of physics are the same, but they differ because they contain different organisms, and many key processes are under biological control, including seed dispersal, predation, herbivory and decomposition. The major biological differences between regions result largely from the interaction between phylogeny, plate tectonics, and past climates and sea levels. Most modern rainforests are on fragments of the Mesozoic southern supercontinent of Gondwana, which drifted apart during the Cretaceous and early Tertiary. The fragments were widely separated during the period when most rainforest genera and many families evolved. Barriers between the major fragments have generally declined since the Miocene, but the absence of rainforest connections between the regions has maintained much of their distinctiveness.

The Neotropical rainforests are the most extensive, the most diverse for plants, birds, butterflies and many other groups, and in many ways the most distinctive. The rainforest vertebrate fauna includes: groups of possible Gondwanic origin that radiated in South America during the long period of isolation (e.g. sloths, anteaters, suboscine passerines); groups that arrived during the period of isolation (e.g. primates, caviomorph rodents); and groups that arrived only after the Panama land bridge connected South America with the north 3 million years ago (e.g. carnivores, deer, squirrels). The most distinctive botanical feature is the abundance and diversity of epiphytes in the Bromeliaceae.

African rainforests were once (c. 30 m years ago) as extensive, diverse and distinctive as those of the Neotropics, but intermittent connections to Eurasia since the Miocene have reduced their distinctiveness and the drying of the continent has reduced their diversity and extent. Today they are mostly drier, lower, more open, and less diverse than the other major regions. Most major families of plants and animals are shared with Asian rainforests, but very few

species. The most distinctive features of Southeast Asian rainforests are the everwet climate, the dominance of dipterocarps and – probably related to both of these – the supra-annual pattern of community-level mass flowering and mast fruiting. The latter results in an irregular alternation of brief “feasts” and prolonged “famines” for animals dependent on flowers, fruits or seeds.

New Guinea and Australia were joined during Pleistocene low sea levels but have never been connected to Asia, so the contrast across Wallace’s Line is sharp, despite the relative proximity of the two regions. Rainforest covered much of northern Australia in the early to middle Miocene, but has since become restricted to a tiny area in the northeast by drying. Rainforest in New Guinea, in contrast, largely occupies land that was uplifted above sea level only 10-15 million years ago. The lowland rainforest flora of New Guinea is largely Asian, while the vertebrate fauna is largely non-Asian. Rats and bats are the only native placental mammals. Marsupials fill the mammalian herbivore, frugivore and small carnivore niches, but there are no large mammalian carnivores. The bird fauna includes some Asian groups and several endemic families, such as the birds of paradise.

Madagascar has been isolated for 90 million years by a deep ocean barrier. The entire non-flying mammal fauna of 101 species has resulted from only 4 colonization events: an ancestral lemur c. 65 m years ago, an ancestral carnivore c. 20 m years ago, an ancestral insectivore, and an ancestral rodent. Other groups show the same pattern: very few colonization events followed by adaptive radiation into a wide range of habitats and niches. Many groups are absent, such as woodpeckers and grazing mammals, and mass extinctions of large vertebrates followed the arrival of the first humans c. 2000 years ago.

What are the consequences of these differences? In theory, convergent evolution could ensure that niches are filled from whatever lineages are available, but, although there are clear examples of convergent evolution in some groups (e.g. flycatching birds), convergence is incomplete in others (e.g. frugivores and browsers). Non-convergence is most obvious for Madagascar and New Guinea, where many vertebrate niches appear to be unfilled, but there are also striking examples from the three largest and most diverse regions (e.g. leaf-cutter ants are confined to the Neotropics). Do these differences in the organisms present have any consequences for community function? The lack of comparable measurements between sites with matched physical environments makes this question almost impossible to answer at present.

Primack, R.B. and R.T. Corlett (2005) *Tropical Rainforests: An Ecological and Biogeographical Comparison*. Blackwell Science, UK.

### ***Seed Dispersal***

**Richard T. Corlett**

**University of Hong Kong, China**

Adult plants are fixed in space for their whole lives. However, movement is essential at two points in the life cycle – during sexual reproduction (i.e. pollination) and during the dispersal of offspring (i.e. seeds) away from the parent plant. Seed dispersal has two potential benefits for the offspring: it gets the seed away from the immediate surroundings of the mother plant, where competition with both parent and siblings is greatest and pests and pathogens are concentrated; and it increases the chance of the seed getting to a suitable site for germination, establishment and growth.

Dispersal by wind depends on the aerodynamic properties of the dispersal unit (seed or fruit), the height at which it is released, and the wind speed during its fall. Seeds will be dispersed further if they fall slowly, from a great height, or in strong winds. The terminal velocity of a seed is strongly correlated with its wing loading (weight per unit area), which can be

decreased by wings, plumes etc. In tropical rain forests, wind dispersal below the canopy is only practical for the smallest of seeds (e.g. orchids) and spores, but it is quite common among emergent and upper canopy trees, climbers, and also pioneers of open sites. Most tropical forest plants are dispersed by animals. Ants are important mostly in the secondary dispersal of small seeds that were initial dispersal by vertebrates, although some plants produce seeds or fruits that are targeted directly at ants. Seed dispersal by vertebrates may take place externally or internally, but internal dispersal is most important by far in tropical forests. Internal dispersal requires that the seeds are packaged in nutritious tissues that are advertised.

Dispersal relationships in tropical forests are extremely diverse. In the tropical Asia, most species of forest birds and mammals eat at least some fruit, and specialized frugivores range in size from 5 g flowerpeckers to 1.5 kg flying foxes, 2-3 kg hornbills and 70 kg orangutans. These frugivores differ not only in diet and size, but also in locomotory and sensory capabilities, fruit and seed handling techniques, digestive physiologies, gut passage times and ranging behaviors. Most animals that eat fruits are capable of dispersing some seeds, but the consequences for a plant's fitness of its fruit being eaten by different animals vary greatly. Fruits, too, vary tremendously in phenology, size, morphology and chemistry, and thus also in their potential contribution to animal fitness. The number of possible pairs of plant-frugivore is enormous, but fruit-frugivore relationships in tropical forests are structured in a variety of ways, so only a small subset of the possible interactions actually occurs.

Frugivores are more likely to be attracted to fruits that signal their ripeness by colour or odour cues tuned to their particular sensory capabilities, and may overlook fruits that do not. Different crop sizes and degrees of ripening synchrony may also attract different types of frugivores. Fruit and seed size interact with the size, gape width and oral processing capabilities of frugivores. Frugivores also differ in their ability to reach fruits displayed in different positions relative to potential perches, while mechanical barriers to the fruit rewards will restrict access to animals with the necessary strength or skill to overcome them. The nutritional content of the fruit pulp will interact with the digestive capabilities of the consumer, while the non-nutrient chemical content could potentially narrow the range of consumers. Discrete plant guilds are most obvious among species dispersed largely by primates, by fruit bats, and by terrestrial mammals. The lengths of the fruit lists compiled for well-studied animal species suggest a general lack of specialization among frugivores, but when the quantity of each fruit species consumed is taken into account, there is much less overlap in diet between animal species. The most important dispersal agents in tropical Asian forests are a few families of birds (Megalaimidae, Bucerotidae, Columbidae, Pycnonotidae, plus some species from a wide range of other families) and mammals (Pteropodidae, Cercopithecinae, Hylobatidae, Viverridae, plus some large terrestrial herbivores and some scatter-hoarding rodents).

Post-dispersal processes, such as seed predation, may effectively decouple patterns of plant regeneration from patterns of seed dispersal, making it very difficult to assess the conservation consequences of frugivore losses. Although dispersal relationships may be less specialized than those for pollination, the animals that disperse seeds are, in general, much larger than the animals that pollinate flowers. This makes them more vulnerable to both forest fragmentation and direct exploitation. Complete failures of dispersal mutualisms may be rare so far, but changes in the composition and spatial pattern of the seed rain must already be widespread. In the longer term, this will inevitably lead to the erosion of plant diversity.

### ***Plant population ecology***

**I Fang Sun**

**Tunghai University, Taiwan**

“Why are there so many tree species in tropical forests?” is one of the central questions in plant ecology. There are quite a number of hypothesis to explain the coexistence of species, such as

intermediate disturbance hypothesis, enemy hypothesis (Janzen-Connell hypothesis), fluctuating recruitment hypothesis, source-sink hypothesis, and recruitment limitation hypothesis. Among these hypothesis, enemy hypothesis has received the most attention and many studies have been carried out to test this hypothesis.

The enemy hypothesis generally states that host-specific predators and pathogens cause density-dependent mortality in the seeds, seedlings and small saplings of their host tree species that is sufficiently strong to limit the local adult density of their specific host tree population. If each tree species exhibits negative density dependence, then more species can coexist because no single tree species can become completely dominant.

If enemy hypothesis is true, then we should expect to see the distance between mother tree and the first year seedlings will be shorter than those of second year; and distance between mother tree and the second year seedlings will be shorter than those of the third year seedlings, and so on. Therefore, a simple but indirect way to test this hypothesis is to compare the distance between mother tree and different age seedlings. If old seedlings are further away from adult tree than young seedlings, then we can assume that Janzen-Connell effect is operating in this forest.

Methods – We will choose a dominant species in Khao Chong which has flowered frequently in the past 20 years. We will select five isolated adults (at least 50m apart) that reproduced during last flowering season, count and measure all seedlings within 25 m radius of the adult tree, calculate the average distance between adult tree and different size seedlings (<20cm, 20-50 cm, 50-100cm >100 cm, 4 categories), and see whether or not the results support our prediction.

## **Pollination**

**David Roubik**

**Smithsonian Tropical Research Institute**

Pollinators are an angiosperm's way of making more plants. The flowering or seed plants exploit bees, flies, wasps and beetles, butterflies, bats, birds or to other vertebrates but pay a dear price for their services. However, it is the only way of doing reproductive business, especially in tropical forests, where the nearest conspecific may be kilometers away. Food, synchrony and deception are the key factors. Different cues trigger innate responses in pollinators to colors, odors or floral displays that are quantified visually. These cues are reinforced by plants which provide a particular kind of reward, usually carbohydrates and protein. Plants and pollinators share their ecological discourse with a variety of 'floral parasites' who usurp the resources of the hard-won pollinator-plant relationships. In the plant reproductive structures, all hell breaks loose as plants compete with each other for reproductive superiority. Maternal plants (those making the seeds and fruit) are choosy about which ovules they allow to mature; bud, floral, and fruit abscission are common. On the other hand, after pollination there are 'aggressive' seeds demanding nutrients and maternal resources.

As indicated in the excellent pollination biology text by Kearns and Inouye, there are three general areas of pollination biology. The first concerns interactions between animals and the reproductive structures of plants. The second concerns which pollen germinates on the stigma and fertilizes the ovule, and the third concerns the growth and survival of the offspring resulting from pollination. In field studies, particularly those of short duration, we examine the details in interactions but remain ignorant of the absolute result of pollen transfer and flower visitation. We will explore and explain why this is the case, using quantifiable, observable aspects of flowers plants and their floral visitors.

### **Tropical bees**

**David Roubik**

**Smithsonian Tropical Research Institute**

Bees are curiously the cause of anxiety to some Hymenopterists (those who study bees, ants and wasps) because they arose from within a wasp group, and started to use pollen instead of animal protein. Who cares? Bees are often called Apidae by those taxonomists, but their biologies suggest there are too many differences among them to be contained in a single family. So, therefore, the two long-tongued bee groups are known by the Melittologists as Apidae and Megachilidae, while the four short-tongued bee groups are called Halictidae, Andrenidae, Colletidae and Melittidae. We make it hard because we know too much for taxonomy to constrain...! About 95% of bee species have nothing to do with honey or colonies (with queens and workers, and drones). About 20% are parasites. Bees are generally solitary, seasonal, and lay eggs in one or more nests, and then die. Their larvae may develop over a few weeks to several months or even years, and the adults sometimes visit flowers of a narrow range of plant taxa, or may visit many diverse flowers (and other resources) through the year. In the tropics, there are fewer species of bees than in much of the warm and dry temperate zone. We will discuss why this is, and put the bees through some of their paces in the field.

### **Fig diversity**

**Rhett D. Harrison**

**Smithsonian tropical Research Institute, Panama**

*Ficus* (Moraceae) is arguably one of the most important plant genera in lowland tropical rain forests. A brief review of tropical florulas also demonstrates that *Ficus* is the only ubiquitously diverse genus in lowland rain forests. Monoecious hemi-epiphytic figs, constituting independent radiations in each tropical biome, make up a significant proportion of species everywhere, but in Asia dioecious figs have diversified into a variety of niches, making the assemblages of this region especially speciose. Pioneer attributes have endowed figs with tremendous evolutionary flexibility, while long-range seed dispersal ensures that a high proportion of the regional species pool is represented in local assemblages. Species are able to co-exist, because many are extremely rare through limited recruitment opportunities. They are nevertheless able to breed at low densities because they possess an efficient, long-range pollination system. These factors are likely to be important in the diversity of other plant groups in the tropics.

### **Conservation biology in SE Asia**

**N Sivasothi**

**Raffles Museum, Singapore**

So much has been written and said about conservation biology in SE Asia - most of which present despondent predictions and tragic consequences, about how rapid the rate of deforestation is, how many reefs are bleaching and dying, how many species are becoming extinct and all the other terrible things we are doing to a biodiversity hotspot ... But just what exactly do we stand to lose and why? Is hunting the major culprit, or are logging and fires a more serious threat? Aren't there already enough laws and regulations to ensure our children have enough biodiversity to keep them happy for the 22nd Century? Should our economies slow down to ensure we keep hold of Earth's treasure trove of life? Should we not emulate the western economies who appear to have a handle on the situation? The talk will be a wide ranging discussion on these related issues - and may perhaps answer the question: is there any light at the end of the tunnel?

**Molecular ecology****Shawn Lum****National Institute of Education, Singapore**

The field of molecular ecology appears to be growing, both in terms of the number of papers being published as well as the number of people engaged in such work. However, what *is* “molecular ecology”? It might be useful to first look at the role of “ecology” first envisaged by Charles Darwin in his book *On the Origin of Species*. Darwin was interested in the favorable variations that determined which individuals in a population successfully survived and reproduced in what he termed the “struggle for existence”. Individuals that prevailed in this struggle passed these favorable variations to their offspring, and were deemed to have been “naturally selected”. For Darwin, understanding ecology was critical in demonstrating how natural selection was the primary mechanism by which evolution took place.

There are a number of different sub-topics subsumed under the broad umbrella of “molecular ecology” – or rather, studies published in journals dedicated to “molecular ecology” (such as Blackwell Publishing’s *Molecular Ecology*) come from a wide variety of fields. For example, these might include population genetic studies that use molecular markers to determine the degree of variation present within and between populations. Other studies that one often encounters in such journals are those that might be more accurately categorized under the heading “molecular evolutionary biology”. Such papers may investigate the phylogeny of a group of organisms and use a molecular clock approach to estimate the divergence times between lineages. Molecular evolutionary research may also look at the genes that are involved in determining certain morphological or physiological traits that distinguish sets of closely related species. Finally, there are studies in “molecular ecology” that actually have an ecological focus – these might include investigations of gene flow (pollen flow and seed dispersal), and at times may include field observations as well. Another area that falls under the ambit of molecular ecology is conservation genetics.

Molecular evolutionary biology has moved beyond the comparing of DNA sequences to measure similarity/divergence between organisms. Researchers now routinely look at genes that might have been involved in the speciation process from a common ancestor. Will molecular ecology similarly integrate molecular biology into ecology? Instead of using molecules as markers, perhaps in the future molecular ecologists will focus on variation in genes and their effects on individual fitness. This would bring molecular ecology firmly into a Darwinian framework, whereby researchers will better understand the genetic basis for the preservation of certain individuals in the struggle for existence.

***Figs and fig wasps: an intricate interaction*****Rhett D. Harrison****Smithsonian tropical Research Institute, Panama**

Figs (*Ficus*, Moraceae) are important plants in lowland tropical rain forests. Over approximately 80-90M years they have co-evolved with fig wasps (Agaoninae, Agaonidae, Chalcidoidea) in an intricate mutualism. The fig inflorescence is a closed urn-shaped receptacle lined with tiny uni-ovular flowers. Female fig wasps enter the inflorescence through a tiny bract covered entrance, losing their wings in the process, and pollinate the flowers inside. Simultaneously, the fig wasps attempt to oviposit on some ovules. Ovules that receive a wasp egg form a gall and the fig wasp larva feeds on the gall tissue. Pollinated ovules missed by the wasps develop into seeds normally. The fig wasp is thus a seed predator – pollinator, and well illustrates the fact that mutualisms are perhaps best understood as mutual exploitation. After approximately one month the adult fig wasp offspring emerge. The wingless males emerge first and mate with the gall-enclosed females. The females then emerge and collect pollen, either passively or by actively filling pollen pockets on the meso-thorax. Meanwhile, the male wasps cut a tunnel through the

fig wall, which the female wasps use to escape from the fig. The adult female wasps live only 1-3 days and thus must locate a receptive fig within this brief lifespan to reproduce. However, figs often occur at low densities and only a small proportion of individuals are receptive at any point in time. Thus, in their search for receptive trees fig wasps disperse further than known for any other pollinator (>10 km), which they achieve by flying above the canopy and using the wind.

A few days after the emergence of the fig wasps the fig inflorescence softens and ripens into a fruit (pseudo-carp) that is eaten by a variety of vertebrate seed dispersers. Over 1200 species of vertebrate feed on figs worldwide and the year round availability of fig fruit makes figs a critical component in the diet of many species, especially at times of the year when few other fruit are not available.

The monoecious system described above is the ancestral system in figs, but in Asia there are many dioecious figs in which the sexual roles are separated. On female trees the fig wasp enters the inflorescence and pollinates the flowers, but fails to lay its eggs because the styles are too long. It, therefore, dies without reproducing. It may be considered a deceit pollination system. On male trees the flowers are modified to receive a wasp egg and only wasps and pollen are produced; the male role of the fig.

The alignment of the reproductive interests of the fig wasp with pollen delivery has led to an incredibly efficient pollination system in figs and the fig - fig wasp interaction has often been used as a model system to investigate co-evolution and other aspects of evolutionary theory. The theory of evolution by natural selection is simple in concept but difficult to prove in practice (largely because evolution proceeds too slowly). However, in some special cases it is possible to predict how an animal or plant should respond (i.e what is the evolutionary best strategy) and then investigate to see whether or not the prediction is borne out. Figs and fig wasps have been used to test various evolutionary theories such as sex ration theory (Local Mate Competition), the evolution of virulence, co-adaptation and co-speciation.

Practical – Dioecy is the derived condition in figs. In the monoecious figs (ancestral condition) the inflorescence must perform the dual roles of seed production and dispersal (female role) and wasp production and pollen dispersal (male role). In dioecious figs these roles have become separated to different plants enabling the sexes to specialise. Through comparative study, we will investigate the general question of sexual specialisation in figs.

### **Ant ecology**

**David Lohman**

**Harvard University**

Ants belong to the single family Formicidae of the Hymenoptera, an order which also includes the wasps and bees. Formicidae is divided into about 14 subfamilies, each of which has a suite of defining morphological and sometimes behavioral characteristics. We will briefly examine the evolution of ant morphology and lifestyle in relation to current hypotheses of ant phylogeny, before considering ant ecology and behavior in more depth.

Coordinating the members of an ant colony is accomplished not through top-down control from a dominatrix-like queen. Rather, it is an emergent property of the same behavioral-genetic programs played out among many independent entities (workers) and coordinated by a complex system of chemical communication. The highly efficient yet decentralized control of the colony is of interest to engineers and computer scientists, who apply research on ant behavior toward the design of new computer programs, networks, and robots.

Ants have evolved complex systems of chemical (and sometimes vibrational) communication to coordinate their activities with nestmates and symbionts. Alarm pheromones, trail pheromones, and colony odor play important roles in colony life. A number of insects have developed the ability to produce or acquire one or more pheromones used by a particular ant species, and thus live in close association with that species, often as parasites.

Many insects and plants have mutualistic symbioses with ants, and the ants are commonly plied with nutrients in exchange for protection. These nutrient rewards for ants are presumably costly to produce, and the ants' partners use a variety of intriguing mechanisms to optimize their energy investment in these rewards. We will be examining ants' preferences for particular nutrients in the field.

Because of their ubiquity and small size, it is relatively easy to collect whole ant colonies or perform ecological and behavioral field experiments. Before our foray into the field, we will review some of the practical aspects and well-guarded secrets of working with ants as experimental organisms.

## Excursions

### Visit to Kantang Mangrove, 20 June 2005

Lumyai Ittichan, Mohd. Hasmawi Ajamain & Sawat Sanitjan



Kantang mangroves was the first destination of several excursions made by the CTFS-AA International Field Biology Course 2005. We arrived at the Kantang Mangrove Ecology Research Station, about 30 km from the Khao Chong, and were welcomed by Dr. Sarayudh Bunya vejchewin. After a short briefing, participants were taken to two experimental plots by boat. After visiting the experimental plots, participants went to see the aquaculture activities in the area surrounding Kantang mangroves. Some of the aquaculture activities that have been introduced were the mussel farming, fish farming and crab farming.

Mangroves are a specific type of forest that is found along coastlines and river mouths that are influenced by tides.

The environment needed to sustain mangroves requires warm oceanic currents, so mangroves are only found near the equator. Mangrove forest has both important ecological and economical functions. A 14 year old growth of *Rhizophora* forest was introduced by Dr. Sarayudh to the participants. He explained that this area used to be logged but logging of mangrove forests has been banned since 2003. Mangroves are known to function as a good nursery ground for a variety of aquatic creatures such as fish, prawns, shell fish and several types of crabs and thus have a high economic value. There are several types of farmed aquatic creatures such as the green mussel (*Perna viridis*), Serated Mud Crab (*Scylla serrata*) and Sea Bass (*Lates calarife*).

At Kantang five species dominate the area, *Rhizophora apiculata*, *R. mucronata*, *Bruguiera sexangular*, *B. cylindrica* and *B. parviflora*. Mangrove forest regeneration is peculiar. Seeds germinate on the twig. The young plants then fall from the twig. If it falls during low tide, the root penetrates the mud, which permits good growth. However, if plants fall during high tide, they float along with the current and are dispersed to new muddy areas, but most die.

Trials for planting mangroves tree species were started in 1968 at Kantang as a means to find out the best planting distance to use in mangrove forest. Two species of mangrove tree were used for this purpose, *R. apiculata* and *B. parviflora*. Dr. Sarayudh explained that the best planting distance proved to be between 1.5 m. and 3 m. Dr. Sarayudh added that, the best duration of crop cycle was 10-12 years, much shorter than normally recommended. If the crops were left for more than 12 years, problems like root competition occur and affect the stand yield.

The principle threat to mangroves in SE Asia is the rapid clearance of forests for aquaculture activities, especially shrimp farming. Most of aquaculture projects are carried out on a large scale and, therefore, large areas of mangroves forest are cleared.

### Para-rubber Plantation, 23 June 2005

Dayantha O.W., Tan Jingmei Eunice, & Thanakorn Lattirasuvan

We visited a para-rubber plantation located near Khao Chong, Trang Province on 23rd June 2005. Since 1901, para-rubber trees (commonly known as rubber trees) have been cultivated in Thailand. With an annual production of 1.5 million tons, Thailand is the world's biggest producer of natural rubber and together with Indonesia and Malaysia generate 75% of the world production. The main markets are the USA, Germany, Italy, Great Britain, Japan and South Korea.



The rubber tree needs an average annual temperature of 27° C and a yearly rainfall of approximately 2000 mm. From around seven years of age, the latex is harvested by cutting the rubber tree bark around the stem and allowing the inner bark latex to collect in coconut husk cups. Cutting is performed at about 4 am. The milky white sap runs into the coconut cups and is collected several hours later. Several students had the opportunity to try their hand at rubber-tapping. Trees are tapped for three consecutive days and left to recover for a day. Latex is not harvested between March and May as the latex yield is low due to the dry season. The plantation owner demonstrated the processing of the latex. The white latex was filtered and mixed with formic acid and water. After approximately 15 minutes, the latex coagulates. It is then manually compressed and machine-pressed into a sheet before sun drying. During the drying the rubber changes color from white to light or dark brown. The dried mats are then sold to factories where rubber items are produced. Most are used to make car tyres.

### **PlanToys® Factory, 23 June 2005**

*Dayantha O.W., Tan Jingmei Eunice, & Thanakorn Lattirasuvan*

The PlanToys® Factory near Trang was established in 1991. The toys aim to promote fun, and stimulate the educational development of children. PlanToys are the first and only preservative-free rubber-wood toys on the market. For many toy vendors the distinction between renewable wood materials and environmentally unfriendly plastics is an important one. Plastic toys are not easy to recycle, do not break down in landfills and also deplete the world's oil resources. The carcinogens present in plastics have also been identified as potential health risks. Although it is more complicated to work with preservative-free rubber-wood, as every single process needs to be kept clean, this protects children in case of accidental consumption of toy parts. The process is also environmental-friendly, since chemical pollution is eliminated.

The company uses wood from plantation-grown trees, naturally processed and free of chemicals. After approximately 25-30 years, latex production wanes and rubber trees are harvested for timber, mostly charcoal and furniture production. PlanToys® provides an alternative outlet for high quality rubber-wood products. PlanToys® success is evident from its achievements, such as being the first Thai wooden toy company to receive ISO 9001-Quality Management Certification in 1999 and also ISO 14001 for environmental care. We visited the factory museum which showcased the company's products as well as local Thai toys, made

from materials such as coconut husk, bamboo and wood. We also got an insight into the production process from the tour around the production line. The company produces a large array of toys from railway sets to dolls.



### Thung Kai Peninsular Botanic Garden, 23 June 2005

*Liam anak Dibor, Sampath Wahala & Shao-chang Huang*

Participants of the CTFS International Field Biology Course 2005 visited the Peninsular Botanic Garden on 23rd of June 2005. The Botanical Garden is located in Thung Khai district of the Trang province. It was established in 1993 by the Royal Forest Department of Thailand, with the following objectives;

- To display plant resources in their natural habitat
- To be a place of botanic study
- To preserve and collect plant species in their natural environment
- To be a area for outdoor recreational activities

The garden is located in a part of Thung Kai Forest Reserve and consists of approximately 4.16 km<sup>2</sup> of natural forest, a n area of peat swamp forest, and a taxonomic garden.

The natural vegetation is lowland evergreen forest, peat swamp forest and semi-natural secondary vegetation. Lowland evergreen forest is dominated by the family Dipterocarpaceae and the vegetation shows stratification, namely a discontinuous emergent and canopy storey, with height of between 25m-30m, and a continuous sub-canopy. The dominant canopy and emergent species are *Anisoptera costata*, *Cotylelobium melanoxyton*, *Dipterocarpus bandoi*, *D. kerrii* and *Shorea roxburghii*. The continuous sub-canopy copries trees with a height of between 15m and 20m and dominant species include *Eleocarpus robustus*, *Vatica odorata*, *Terminalia* sp., *Carallia brachiata*, *Schima wallichii*, *Artocarpus rigidus* and *Peronema canescens*. The understorey consists of trees with a height of 10m-15m and is dominated by *Diospyros* spp., *Phoebe* spp., *Fragrea frarans*, *Careya sphaerica*, *Aglaia* sp. *Dillenia obovata* and *Sureguda multiflorum*.

Peat swamp forest grows in fresh water marshy areas over a thick layer of peat. The



Peat swamp forest at Thung Khai is comparatively small compared with other parts of Thailand and Malaysia. The upper layer of the forest is dominated by the family Anacardiaceae; *Pentaspadon velutinus*, *Camptosperma auriculatum*, and *Buchanania arborescens* are common among the family. The middle story is dominated by *Heritiera littoralis*, *Baccaurea bracteata* and several *Syzygium* species. A nature trail constructed through the peat swamp, gives the opportunity to visitors to observe and admire the forest closely.

A taxonomic garden is located around the

administrative buildings. Tree species belonging to 22 main families have been planted within this area, mainly for demonstration purposes.

A recently constructed canopy walk way is located along the nature trail. The maximum height of the walkway is about 25m, and the length is about 125 m and gives a bird's eye view of the forest.

The "Arbor for Love Garden" was established in the year 2000. This garden provides an opportunity for newly married couples to plant a tree in memory of their wedding. Presently the garden has about 512 trees planted by couples and others who enjoy trees. Every year the management of the botanical garden, send growth measurements of the particular tree to those who planted it. At the end of our excursion all the members of the CTFS-AA International Field Biology Course planted a tree in the garden.

### **Doi Inthanon National Park, Chiang Mai, 27 June 2005**

*Bharath Sundaram, Hazel Consunji, & Nuansri Petcharat*



On June 26 2005, the course travelled to Chiang Mai in northern Thailand, for a 5-day field trip. Our first stop was the Doi Inthanon National Park. The park is situated in parts of Sanpatong District, Chomthong District, Mae Chaem District, Mae Wang District, and Toi Lor Sub-district of Chiang Mai Province with an approximate area of 482 km<sup>2</sup>. The National Park consists of high mountains, including Doi Inthanon, which is the highest mountain in Thailand (2,565 m). It has cold weather and high humidity throughout the year, particularly on the top of the mountain. In winter, the temperature at the National Park can reach

below 0°C. In summer, despite hot weather in central Chiang Mai and nearby districts, it is still very cold on the top of Doi Inthanon. The forests in the park are one of the Thailand's most significant and valuable heritage sites. Forest types include moist evergreen forest, pine forest and mixed deciduous forest, where you can find economically valuable wood like teak and mountain pine. In addition to these, there are many beautiful and endemic flowers such as the vanda orchid, *Phycastylis* and *Rhododendron*. *Sphagnum* moss and osmanda fern are found at higher elevations in the park.

We went up the summit of Doi Inthanon, which was clothed in a heavy mist and a slight drizzle. We had a good introduction to upper montane forest by walking along the various trails near the summit. We also spent some time in the souvenir shop.

Our second stop was the Doi Inthanon Forest Dynamics Plot. A 15 hectare plot (500m x 300m) located on the middle slope of the mountain at an elevation of about 1700 m. The plot is montane forest, receiving a typical monsoonal climate with a 5-6 month dry season. The mountains of northern Thailand are divided into basic two zones: the lowland zone from 0 to 1000 m, dominated by deciduous forest, and the montane zone above 1000 m, dominated by evergreen forest. The montane forest is further divided into lower and upper montane at approximately 1800 m. An upper montane forest has a shorter canopy height and lower species richness than lower montane forest, although they share many tree species. The plot lies near the transition zone from lower montane forest to upper montane forest, which is evident in its forest structure and vegetation. Canopy height varies from 15-30 m in the upper slope area to 50 m in the lower slope area. There are small gaps within the plot but no large-scale natural disturbances have been recorded. There is, however, occasional human disturbance since the

plot is near the road making it accessible to hunters and plant collectors. The plant families Fagaceae and Lauraceae dominate the plot in terms of basal area, while Lauraceae also dominates in terms of the species richness (25 species out of a total of 145 species).



Our last stop for the day was the Doi Inthanon Royal Project. Northern Thailand faced serious problems during the 1950s and 60s. Increasing human populations, primarily tribal, coupled with land degradation caused by slash-and-burn agriculture, resulted in serious ecological and socio-economic problems. Land degradation impacted watersheds and soils in the area. Moreover, the tribal people of the area, mainly Karen and Mon, relied on opium as their only cash crop. While the cultivation of opium was banned in 1959, an alternative livelihood source was not identified. The Doi Inthanon Royal Project (DIRP) was set up in 1969 to address these issues. The four goals

of the DIRP are (a) to enhance human welfare, (b) to conserve natural resources for a sustainable future, (c) to eradicate opium poppy cultivation and opium derived addiction problems, and (d) to encourage a wise and proper balance in utilising and conserving land and forest resources. Spread over an area of 104 ha, the DIRP's main activities are horticultural, while additionally serving as the centre for processing and packaging of all produce from the Doi Inthanon area. One of the focal areas of the DIRP is hydroponics, the science of growing plants without soil. Technicians at DIRP use styrofoam containers with a constant supply of nutrients in solution. Many leafy vegetables such as lettuce and leeks are grown this way. Most of the produce in the DIRP is organic, and Integrated Pest Management is employed as an alternative to conventional application of chemical pesticides.

The DIRP also has an impressive nursery set up to grow flowers of different species and varieties. We learned that the marketing of roses is beset by patenting problems, and that certain varieties can only be marketed by paying a royalty to the owner of the variety. The DIRP, in an effort to avoid patenting problems, is in the process of developing their own varieties. We rounded off the excursion by visiting the souvenir centre, which is well stocked with handicrafts, seeds of flowering plants, and various trinkets.

### **Doi Suthep-Pui National Park, 28 June 2005**

*Chan Yoke Mui, Huang Pien & Warin Wannaprapho*

Doi Suthep-Pui National Park is located about 5 km west of Chiangmai in northern Thailand and covers 262.5 km<sup>2</sup>. It was established in 1981 and Doi Suthep, Doi Buakha and Doi Pui are the main peaks of the granite mountain in the park. Doi Suthep, the highest peak, is 1,685 m.

The park receives annual rainfall of about 2,000 mm, and the rainy season is from May to October, with the monthly rainfall of about 200-400 mm. Rainfall during dry season is only about 30 mm per month. The average annual temperature is 16°C.

The park has three types of forest, hill evergreen forest, mixed deciduous forest and dry dipterocarp forest. The evergreen forests are found at elevations above 1,000 m where rainfall is higher. Mixed deciduous and dry dipterocarp forests are found below 1,000 m. These forests shed their leaves during dry periods.

a) Dry deciduous dipterocarp forest, mixed deciduous forest, and riparian forest

The dry dipterocarp forest is very near to Chiang Mai, and was previously logged and disturbed by shifting cultivation (Mon hill tribes live in the forest). The forest has a simple structure with

two layers; a canopy of 20-25 m and a sub-canopy of 10-15 m. The canopy is quite open, allowing light to reach the forest floor (Fig. 1). The forest has less than 100 species with three species of *Dipterocarpus* and two species of *Shorea*. The soil is shallow, sandy clay, which favours *Shorea siamensis* as the dominant species. The trees are shallowly rooted, usually 30-50 cm deep. The appearance of bamboos can be an indicator of mixed deciduous forest.



Fig 1 Left picture: Dry deciduous dipterocarp forest, dominated by *Shorea siamensis*. The trees were short and rather young at this stage. Right picture: Stands of *D. turbinatus* – characteristic of mixed deciduous forest.

The forest is prone to man-made fires but the trees are adapted to resist fire. The fire destroys undergrowth and most saplings, and deprives the soil of leaf litter which otherwise would supply organic nutrients to the soil. Due to disturbances from hill tribe communities, large mammals are seldom seen in the park but some deer, barking deer, bears, gibbons, monkeys and lemurs are present. Some 200 species of birds and 500 varieties of butterflies and moths can be found here.

In the gullies between ridges, a high water table allows evergreen species to survive, producing mixed deciduous-riparian forest and housing a higher diversity of species. Dry dipterocarp forest is usually found on upper slopes or ridges, and the forest changes to mixed deciduous forest down the slope and to riparian forest along streams. For example, stands of *Dipterocarpus costatus* on ridges change to *D. turbinatus* downslope. The marked difference between the two stands is that there are more micronutrients in the soils under *D. turbinatus* stands compared to *D. costatus* stands. The trees flower annually and occasionally show masting, but not as extreme as in tropical wet forests.

b) Lower montane evergreen forest

The lower montane forest is dominated by Fagaceae, including *Quercus*, *Trigonobalanus*, *Castanopsis* and *Lithocarpus*. It has one canopy layer 20-25 m tall with clear undergrowth (Fig 2). The soil is sandy clay loam with pH of 4.6-5.



Fig 2 Lower montane forest with clear undergrowth and thin canopy cover, dominated by oak family.

Wat Phra That Doi Suthep is a magnificent Buddhist temple erected in 1384, with naga stairs of 306 steps going up the temple. The temple has gold plated, Peguan-styled pagoda (chedi) which is reputed to contain the remains of the Lord Buddha (Fig 3).



Fig 3 Wat Phra That Doi Suthep

In the afternoon, we visited the Maetaman Elephant Camp. The elephants were bathed by their trainers before performing in a show – soccer playing, flower painting (elephant paintings made into t-shirts are sold for about 500 baht per piece!), elephant massaging, and other entertainment (Fig 4).

According to Dr. Sarayudh, the elephants in the camp were domesticated for logging in the past. Since logging activities were banned by the government, the owner of the elephants ventured into the tourism business by setting up this camp, thus giving a second chance of employment to the village people and to the elephants as well. Initially there was a project by the government to persuade elephant owners to work as forest patrols, using elephants as a mean of transportation, but the project was later abandoned because the owners were not satisfied with the low pay given by the government.



Fig 4 Elephants showing their skills and performances at the camp

The government has enacted strict laws for elephant conservation by banning illegal animal hunting and logging, and has set up elephant sanctuaries in natural forest parks to

protect them. However, the setting up of elephant camps is not part of the conservation project, but rather the result of economy factors.

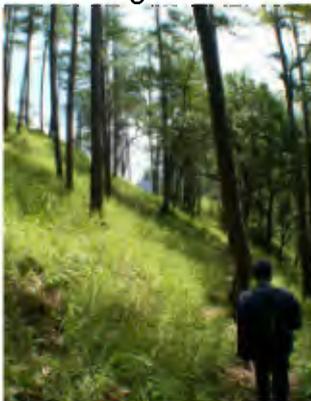
Later, we took an elephant ride around the area for about an hour, which was rather bumpy but quite exciting. We stopped at the souvenir shop in the camp before leaving, which sells varieties of souvenirs but probably the most interesting were the paper products (e.g. bookmarks, envelopes, slippers) made from elephant dung!

### Doi Chiang Dao National Park, 29 June 2005

Juei-Ling Hsu, Po-Hao Chen, & Ronnie Bibi

On 9 July 2005, the course members had a magnificent trip to the mountain of Doi Chiang Dao. It was believed that Doi Chiang Dao was a paradise blessed and taken care of by the gods. Most of the area is undisturbed and that has preserved its beautiful forest. The mountain rises steeply and also catches a lot of rain, which creates varied habitats for wildlife and plants, and makes this place special for rare and endemic species. If you are curious how wet Doi Chiang Dao is, an idea can be gained by watching the mountain from a distance. Cloud and mist inevitably surround the peak.

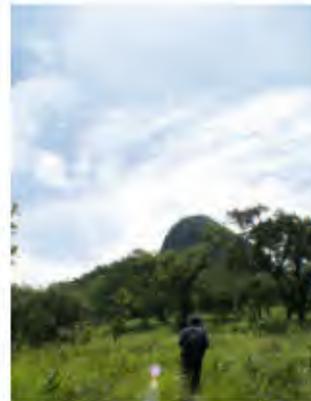
Doi Chiang Dao is 2,225 m high and is the third highest peak of Thailand. Our ride in pickup trucks started from the base of mountain and continued to the top station at 1,440 m. Along the way, we past through several forest types at different elevations. The environment changed quickly as elevation rose. Several 1 ha plots established by Dr. Sarayudh showed that the forest types on Doi Chiang Dao change from dry dipterocarp forest and mix dipterocarp forest to hill pine-dipterocarp forest to low mountain pine forest and finally to rocky alpine shrubs and evergreen trees.



(a)



(b)



(c)



(d)



(e)



(f)

Fig.(a) Lower montane pine forest on Doi Chiang Dao. (b) Alpine grassland with oak trees on Doi Chiang Dao. (c) *Drosera* (Drosophyllaceae). (e) A kind of plant has hairy leaves. (f) One of our guides on Doi Chiang Dao.

We stopped at the Den Yaa Chud the final ranger's station and then started to walk up the mountain. At first, we walked through pine forest (Fig 1a). It was very bright under the forest. The soil was sandy and nutrient must be very low, because we saw many of the plants which belong to the family of Droseraceae and in genus of *Drosera* (Fig 1b). Going higher, we emerged on to an Alpine grassland with oaks and various shrubs (Fig 1c). The trail became rocky and quite hard to walk by foot. Now we understood why local people want to eat long-tail Goral in the hope that they will be able run up the rocks.

Microhabitat variation was obvious. The windward side of isolated trees was wet and dark because the oak trees block the sun light. The leeward side was dryer and brighter. Rocky substrate, strong wind, intensive sunlight and rapid change of temperature make mountain area a special environment with many rare plants and animals. We found several beautiful orchids including of slipper orchids (Fig 1d). We saw the Doi Chiang Dao endemic palm which is found on rocky areas above 1700 m. One of the interesting things to observe is how plants are adapted to the mountain environment. Morph-changes of trees are easily to see. Tree height is reduced to about 10 m but trunks and branches are extremely strong and some plants often have leaves that are very hard, shiny or hairy (Fig 1e). All these characteristics appear to be adaptations to the wind at high elevation.

This place is one of fine example to see the changes of forest structure through the increases of altitude. The forest is similar to other high altitude forests in Thailand. For example, Doi Inthanon and Doi Ching Dao shared quite similar types of forest at lower altitudes. However, the summit of Doi Ching Dao is limestone and hence supports very unusual vegetation, with several endemic species.

### **Kantang mangroves – Mangrove fauna, 5 July 2005**

*Siew Chin Chua, Jing Xin Liu, & Samangi Hewage*

A second excursion was made to Kantang mangroves to learn about the mangrove fauna. This visit was made during low tide, when the mud flats were exposed, and hence we were able to look at the inter-tidal fauna.

There are three basic categories of mangrove faunal communities, namely aquatic, semi-aquatic and terrestrial. The fluctuating water level, salinity and the unstable substrate means that the animals living in mangroves, especially the aquatic and semi-aquatic, have to adapt to the a quickly changing environment.

We were first introduced to some of the interesting fauna found at the back mangroves. *Thalassina anomata*, the mud lobster, makes volcano-like mounds that can be up to 2 m high by excavating the muddy substrate. This helps to recycle nutrients deep underground. The mound creates many microhabitats shared by other animals, such as crabs and spiders. It also provides the back mangrove flora such as sea holly, mangrove fern and *Excocaria agallocha*, elevated ground to grow on. Conspicuous holes in the mud made by various crabs could also be seen.

Thereafter, we visited two inter-tidal sites. The first one was within an old growth *Rhizophora apiculata* dominated mangrove forest. We searched for mangrove fauna for half an hour. There are three forms of animals in this semi-aquatic community. Those attach to tree stems and roots, and which stay quiescent during low tides, active surface crawling forms, and burrowing animals. A rich diversity was collected, despite our inexperience. Some of the fauna we collected included: Crustaceans: *Episesama* spp (Tree climbing crabs), *Uca* sp. (Fiddler crab), *Thalassina* sp. (Mud lobster) (Fig 1b), *Chiromantes* sp. (Face-banded sesarminae), *Episesama* spp. (Tree-climbing crabs), *Metaplex elegans* (Orange signaler crab) and *Euraphia* sp (Star Barnacles); Arthropods: *Coleoptera* larva, *Argiope mangal* (mangrove St. Andrew's cross spider); Molluscs: *Nerita lineate* (Common nerite), *Littoraia* (Mangrove periwinkle), *Cerithidea obtuse* (Mud creeper), *Sphaerassiminea miniata* (Red berry snail), *Onchidium* sp.

(Mangrove slug) and *Enigmonia* sp. (Enigma oyster); Vertebrates: *Periophthalmodon* sp. (Mudskipper) (Fig 1a); Nematoda: Nematode

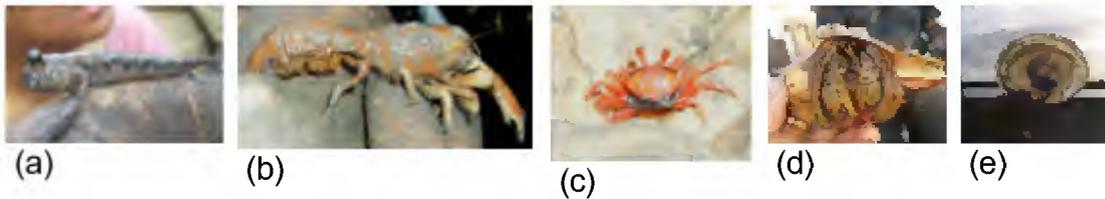


Fig 1 Photographs of some mangrove fauna. (a) Mudskipper, a fish that has adapted to semi-terrestrial life with its modified pelvic fins that allow it to move on mud, mouth and gill chambers that can hold water, breathing skin and large eyes to spot predators. (b) A pregnant female mud lobster that was recently described. (c) A tiny bright red sesarimine crab. (d) Mangrove hermit crab which utilizes empty shells. (e) A mollusk with very translucent shell.

The second site was an open mudflat and the following fauna were found Molluscus: *Isognomon ehippium* (Leaf oyster); Annelids: Tube worms; Crustaceans: *Diogene* sp. (Mangrove hermit crab) (Fig 1d), *Harpiosquilla* sp. (Mantis shrimp); Cnidarian: *Anthenopleura africana* (Mangrove anemone)



Fig 2 Everyone was muddy but happy. (a) Two of the course participants doing the mangrove fauna sampling. (b) Dr. Richard Corlett. (c) Dr. Shawn Lum (d) Sivasothi, who was our guide for this field trip.

The intertidal zone is a hidden treasure trove that is only visible during the low tide. Despite getting very muddy, everyone had a very enriching and fun-filled time getting to know the mangrove ecosystem first hand.

**The field course in colour**



*Field course in colour*



*Field course in colour*



## Group projects

### Spider size determines web size and strand spacing?

*Siew Chin Chua, Jing Xin Liu, & Samangi Hewage*

#### ABSTRACT

Web building spiders can be broadly categorized into orb-web and non orb-web builders. In determining the effectiveness of orb-webs to capture prey, web size and strand spacing are important factors. This project investigates the relationships between spider size and web size, and strand spacing. Nine orb-web making spiders and their webs were sampled irrespective of the species and age. Initial linear regression analysis showed that web size and strand spacing are strongly affected by spider size. However, after removal of outliers the relationships were not significant.

#### INTRODUCTION

Spiders belong to the order Araneae in Class Arachnida, Phylum Arthropoda. Most spiders are small, inconspicuous arthropods harmless to human. They are important predators that keep insect populations in check. Spiders can be divided into web building spiders and jumping spiders which actively hunt for prey. The former can again be categorized into orb-web and non orb-web builders. Orb-webs are two dimensional webs, with silk threads radiate like spokes from a central hub (Ramel 2004).

Many studies (Eberhard 1990; Heiling and Herberstein 1998) of orb-webs show that web size and strand spacing are elements of the web design that affect the web's effectiveness in prey capture. A larger web increases the rate of prey interception. Closer silk strands increase the visibility of the web (Craig 1986) and reduce the size of prey entangled. Interestingly, spiders can also maximize silk use efficiency by adjusting web mesh size in response to the temporal change in size of prey (Sandoval 1994). Other elements of the web affecting prey capture include tension of the web, the number of radii in the web, and the adhesiveness and thickness of the silk (Eberhard 1990).

Silk is created as a proteinaceous liquid produced by special glands within the spider's abdomen. The liquid is transported by a duct to a spinneret at the hind end of the abdomen for silk production. Spiders can produce up to seven types of silk for different purposes (Ramel 2004). Web making is energy consuming hence the size and strand spacing of the web, which are related to the amount of silk needed, is likely to be constrained by the size of the spider. We sampled orb-web building spiders in a patch of forest in Khao Chong to test the following hypotheses.

H1: Web size is determined by size of spider; the smaller the spider, the smaller the web size.

H2: Strand spacing is determined by size of spider; the smaller the spider, the smaller the strand spacing.

#### MATERIALS AND METHODS

##### Study Site

The project was conducted at Khao Chong, Trang Province, Thailand. The study was confined to the lowland rain forest near the park buildings.

##### Data collection

Over four hours, we measured all the orb-webs encountered below a height of 2.5 m. A total of nine spiders and webs were found. We made two diameter measurements of the web 90° to one another, and measured the distance from the center to the 10th strand of silk on the lower

half of the web (Fig. 1a). Strand spacing was this distance divided by ten, i.e. the average distance between two strands.

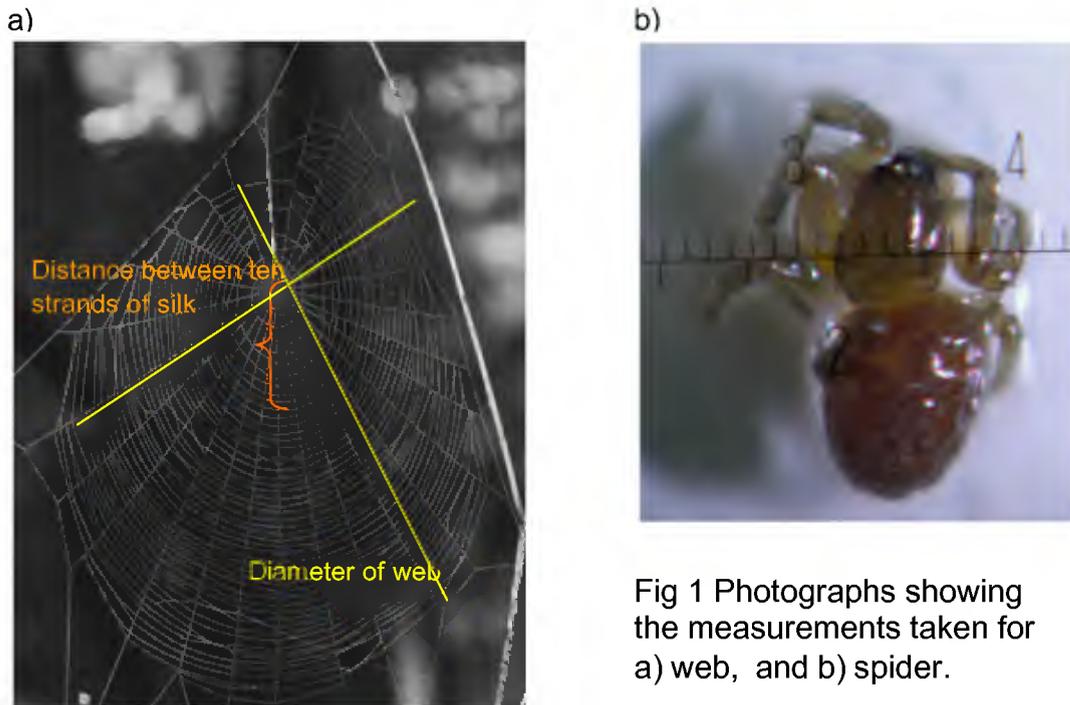


Fig 1 Photographs showing the measurements taken for a) web, and b) spider.

After the web measurements were taken, the spiders were captured using an aspirator, killed in 90% ethanol, and measured under a macroscope. Spiders' size was determined by measuring the width of the head (Fig 1b.), as the abdomen size varies greatly before and after feeding. Width of spider head was also previously found to be a reliable predictor of web dimension in both adult and juvenile spiders (Heiling and Herberstein 1998). Large spiders were measured in the field using a ruler. Where possible, the spiders were identified to family level.

#### Data Analysis

All the data analysis was done using SPSS version 11.5. Data normality was tested by One-Sample Kolmogorov-Smirnov Test ( $P$ -values were 0.225, 0.212 and 0.316 for spider size, web size and strand spacing, respectively). We carried out linear regression between spider size and the other parameters.

#### RESULTS

Summary measurements of nine spiders and their webs are given in Table 1.

Table 1 Summary of the measurements of nine spiders and their webs

	Mean	Std. Deviation	N
Spider size (mm)	1.0189	1.28679	9
Web size (cm)	16.8556	16.08354	9
Strand spacing (mm)	0.2222	0.21082	9

Spider size was found to be a significant predictor of web size and strand spacing (Fig 2). However, we had only one really large spider and after removal of this outlier, the relationships were no longer significant (Fig 3).

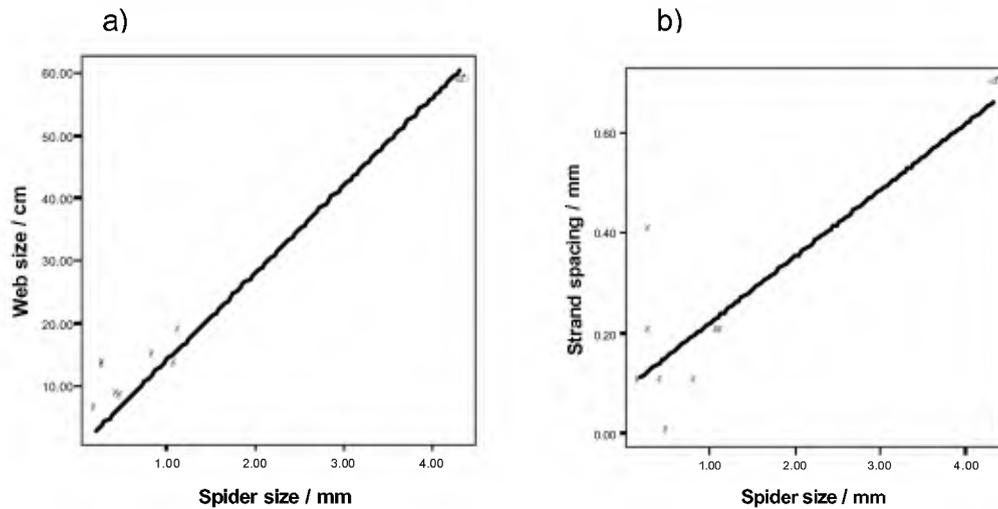


Fig 2. Linear regressions of a) spider size and web size ( $y = 12.23x + 4.39$ ,  $r^2 = 0.96$ ,  $p < 0.001$ ), and b) spider size and strand spacing ( $y = 0.13x + 0.09$ ,  $r^2 = 0.66$ ,  $p = 0.008$ ).

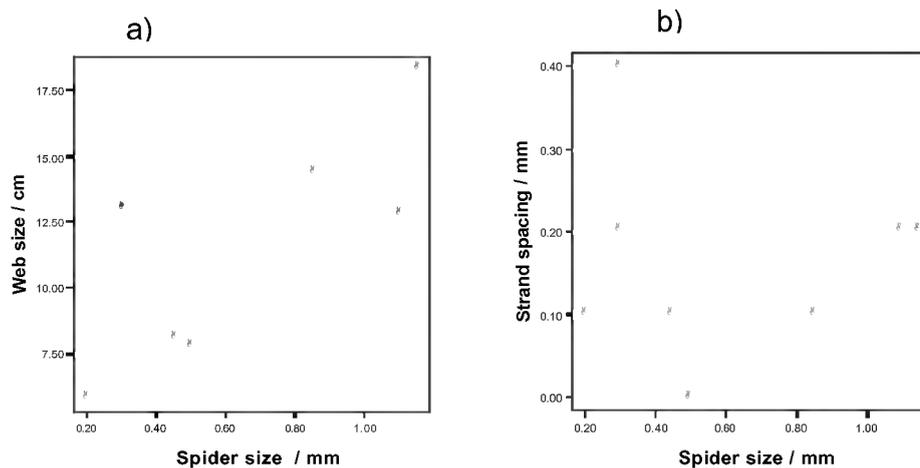


Fig 3 Linear regressions between a.) spider size and web size ( $p = 0.063$ ) and b) spider size and strand spacing ( $p = 0.951$ ) after removal of the outlier.

## DISCUSSION

Our results show that spider size determines web size and strand spacing and that they tend to increase with increasing spider size. This implies that bigger spiders will tend to spin bigger webs, with bigger strand spacing, which will trap larger prey. This might be a strategy in conserving resources, as trapping smaller prey with closer strands is not cost effective energetically, as more silk is needed.

Smaller spiders on the other hand tend to make smaller webs with closer strand spacing. The small web might mean that they are more able to utilize small microhabitats such as between the axial of leaf and stem and among grasses. The smaller spacing of the web, while seemingly more conspicuous, would be compatible with the smaller prey that they are targeting. Smaller prey have smaller field of vision and they would also be easier for the spiders to handle.

However, our sample size was very small, as most of the spiders encountered were non-orb web builders. There was in particular insufficient sampling of large spiders. Most of the

spiders were less than 1.2 mm. Removal of the biggest spider, which was an outlier (Fig 3) resulted loss of significance in the relationships. Heiling and Herberstein (1999) found that strand spacing was only significantly positively correlated with body size of juvenile spiders, not adult spiders. In our project unfortunately, we did not determine the age of the spiders, which could also be a reason for the lack of significance in the relationships.

#### CONCLUSIONS

Although the results tend to support the two hypotheses, more sampling across varying spider sizes is needed and the age of the spiders needs to be determined.

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## Caddisfly nest size in different water flow rates

Juei-Ling Hsu, Po-Hao Chen, & Ronnie Bibi

### ABSTRACT

Caddisflies are aquatic insects and construct chambers in water during their larvae and pupae stages. This study investigated the relationship between nest size and water current. The results showed that the water flow rate does not affect the nest size. However, we found that bigger larvae had larger nests ( $p < 0.05$ ).

### INTRODUCTION

In fresh water ecosystems, *Trichoptera* (caddisflies) are an important component in the food chain. Caddisfly larvae can be shredders-chewers, collectors, scrapers, piercers and predators and they are one of the largest orders of aquatic insects (Unzicker et al. 1982).

The life cycle of caddisfly has four stages; eggs, larvae, pupae and adults. The larval and pupal stages are usually found in aquatic systems, such as rivers, streams, lakes and ponds. Herbivore caddisfly larvae construct a case or net as a shelter. The adult caddisfly is covered with the fine hair and range from 2 mm to 40 mm in length. They have slender, filiform antenna and large compound eyes. Caddisflies can be used to assess water pollution.

Having observed nests in the stream, we hypothesized that the size of nest would be related to physical properties of the aquatic environment. We predicted that water flow rate could be important factor in determining nest size.

### MATERIALS AND METHODS

#### Study site

This study was carried out in the Khao Chong stream, Trang, Thailand (7°33'N, 99°47.4'E). The width of stream was about 5 m. The vegetation beside the river was secondary forest. The bottom of the stream was sandy and rocky. The range of the water flow rate was from 0.118 to 0.725 m sec<sup>-1</sup>.

#### Data collection

We selected 10 different water flow environments to observe the caddisfly's nests. At each site we recorded the water flow rate, nest size, nest position, larvae or pupae appearance, caddisfly species (morpho spp.) and size, and nest weights.

#### Data analysis

We used linear regression to determine the relationship between flow rate and nest size. A t-test was used to compare between two positions of the nests, upstream or downstream of the stone.

### RESULTS

A total of 85 caddisfly nests were found in the Khao Chong stream and three morphological species were identified (Fig 1). Data were separated to three groups: larvae, pupae and empty nests. Nests were divided according to whether they were found on the upstream or downstream side of the stone. Twenty seven larval nests were found, 10 (12%) of which were on upstream side. Fifteen pupa nests, 1(1%) on the upstream side and 43 empty nests were found, 24(29%) of which were upstream (Fig 2).



Fig 1 Three morpho-species of caddisfly collected in the study

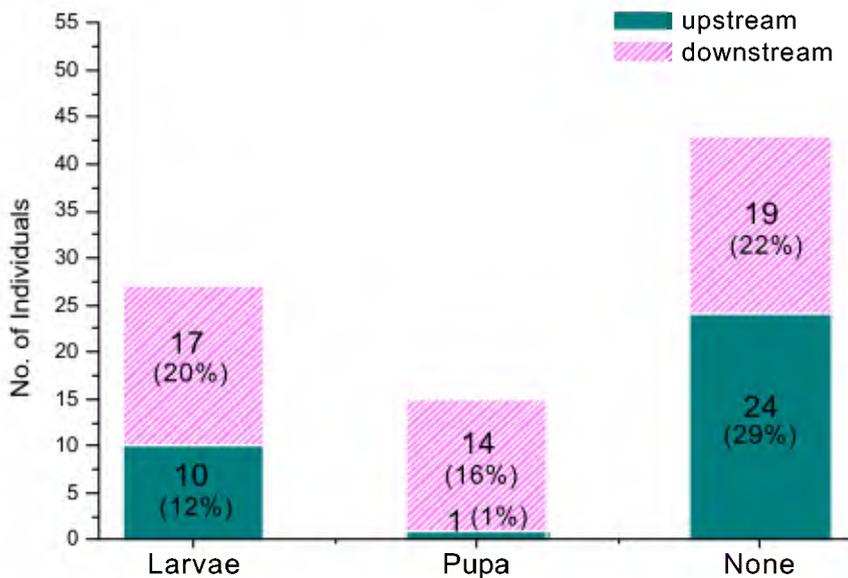


Fig 2 Number of observations of three types of nest (none=no larva or pupa encountered)

There was no significant relationship between water flow rates and the nest volumes in upstream ( $p = 0.05709$ ) or downstream environments ( $p = 0.3772$ ) (Fig 3). There was also no significant relationship between nest volume and water flow rate ( $p = 0.6167583$ ).

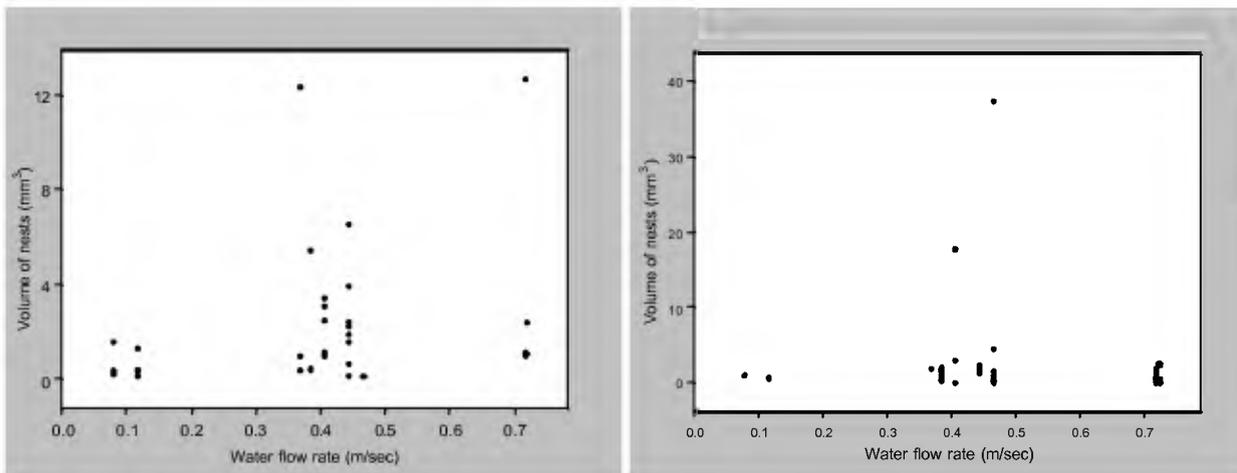


Fig 3 Correlation between water flow rate and the nest volume (left) upstream (right) downstream.

However, there was a positive correlation between larva size and nest volume ( $p < 0.05$ ,  $R=0.2959$ , nest sizes =  $7.2919 \times \text{larvae length} - 5.493$ ) (Fig 4). There was no significant difference between nest volumes of larvae and pupae ( $t = 1.778$ ,  $df = 40$ ,  $p = 0.083$ ).

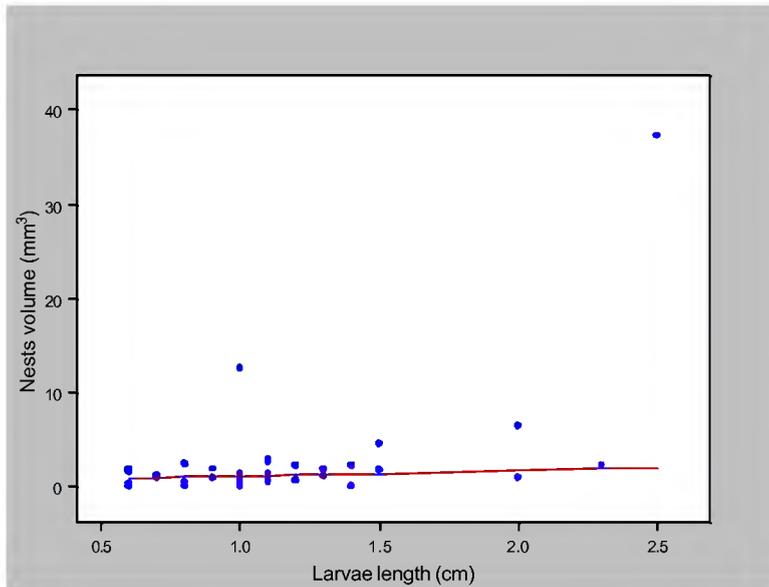


Fig 4 Correlation between nest volume and the larval size.

## DISCUSSION

The results found no significant relationship between nest size and water flow rate on either upstream or downstream sides (Fig 3), contrary to our predictions. The nest size depended only on larval size. However, our methods were rough. We were only able to measure weight to 1 g accuracy. So we could not analyze these data. We also could not measure the exact water flow rate at each nest. The probability that we damaged the nests during data collection was also quite high, and probably affected our results.

Many factors affect nest size in caddisflies such as food resource, oxygen concentrations, elevation, temperatures, up or down stream environment and pattern of rain fall. Water flow rate alone can not reveal the pattern of nest sizes (Neboiss 1981).

Regression analysis showed there was a positive relationship between the nest volume and the larva size. In our observations caddisfly preferred to nest in faster water.

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## The distribution of lichens at different tree heights

Yoke Mui Chan, Pien Huang, & Warin Wannaprapho

### ABSTRACT

Lichens are the product of a symbiotic relationship between fungi and algae. We hypothesised that light and humidity affect the growth and distribution of lichens on tree trunks. Our study found no significant difference in the lichen coverage between the heights, but also no significant variation in the relative humidity at the heights we measured.

### INTRODUCTION

A lichen consists of an alga (termed the photobiont) and a fungus (termed the mycobiont) coexisting as a thallus body (Fig 1). In this symbiotic association, the fungus provides the algae with shelter and nutrients by absorbing mineral nutrients from the underlying surface. In return, the algae photosynthesize to produce sugars and other resources for themselves and for the fungus. For instance, cyanobacteria, in this mutualistic relationship, produce ammonium by fixing nitrogen gas.

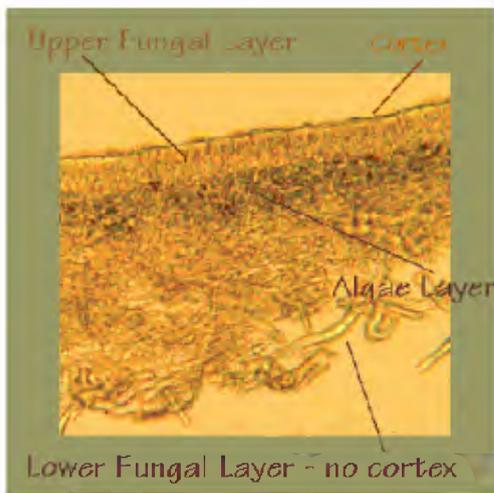


Fig 1 Cross-section of lichen, showing an algal layer in between fungal layers (from Pittan 2004).

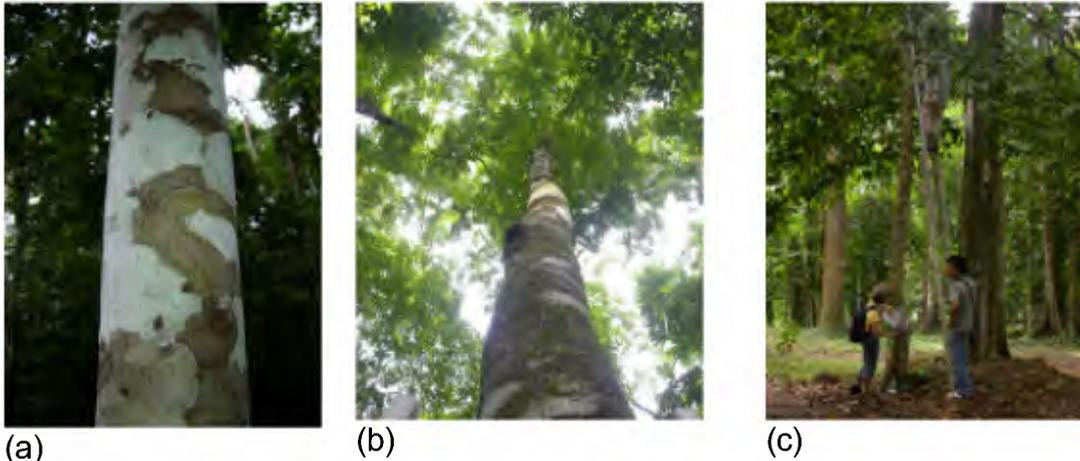
Since algae need light for photosynthesis, lichens are generally not found in very shaded niches. Lichens are able to withstand desiccation and to resume activity after rewetting. Lichens with green algae recover from desiccation by absorbing water from humid air, but lichens that contain cyanobacteria need liquid water to resume photosynthesis (Pittan 2004).

We observed an abundance of lichen on trees in the Khao Chong forest (Fig 2). The physiology of the lichen requires ambient light and humidity so that the algae can photosynthesize, and the fungus can absorb nutrients and water. Based on the assumption that trees are exposed to more light at greater heights, but that relative humidity is greater in the understory, we hypothesised that the abundance of lichen would be greatest in the mid-region of the tree, where it receives intermediate levels of light and humidity.

### MATERIALS & METHODS

Ten trees of various species and sizes near the Ton Pliw Waterfall at Khao Chong were surveyed for lichen cover (Fig 2). Seven trees were sampled in an area with high stem density and a high degree canopy cover and three trees were sampled in an open area, with sparse stem density and high light levels reaching the forest floor.

Frame quadrats (20x20 cm) on plastic sheets were affixed to the trees at different heights and marked for lichen coverage; there were one hundred grids per sheet (Sutherland 2002; Fig 3). Each tree was measured for girth at breast height (GBH), and divided into three height zones (0.5-2.5 m, 2.5-4.5 m, and 4.5-6.5 m). Relative humidity and temperature were measured with an electronic hygrometer and recorded at each height. Three frame quadrat counts were taken at each height on a transect facing East. Due to limitations in equipment, we were unable to measure the light levels at each height.



(a) (b) (c)  
Fig 2 Lichens on tree bark, (a) in a shaded location, (b) in a well lit location, and (c) sampling with a ladder.



Fig 3 Left: field equipment; data sheet, marker pen, humidity meter, tape measure, 20x20 cm frame, rope. Right: frame quadrat positioned for lichen sampling.

Data from the frame quadrat samples was arcsine transformed to a normal distribution, and analysis was conducted using S-Plus 2000 software. An initial analysis of our data revealed that there was no significant difference in the relative humidity and the relative temperature between the heights at which we sampled (mean relative humidity (%) =  $81.8 \pm 4$ , mean temperature ( $^{\circ}\text{C}$ ) =  $30.1 \pm 0.9$ ).

## RESULTS

An analysis of variance (ANOVA) on the lichen coverage at the three heights we measured found no significance between the amount of lichen cover and the height at which the count was taken (Fig 3,  $F_{2,86} = 1.952$ ,  $p > 0.05$ ).

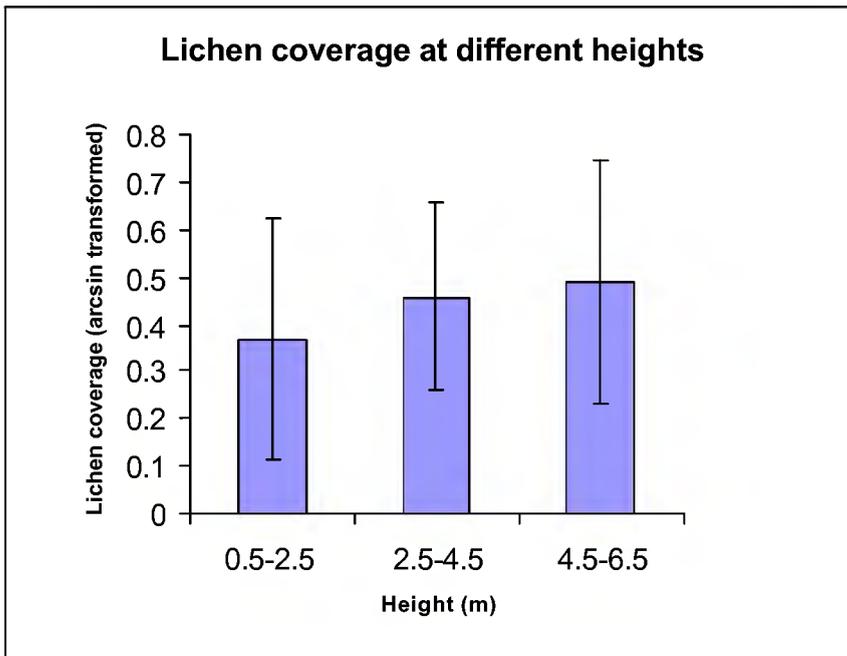


Fig 3 Coverage of lichen (arcsin transformed) was censused at three different heights along of tree trunk.

Using a two-sample t-test, we compared the amount of lichen on trees in the shade versus trees with high exposure to light (Fig 4). Our results ( $t = -1.015$ ,  $p=0.32$ ) indicated that there was no significant correlation between the amount of light exposure and lichen cover.

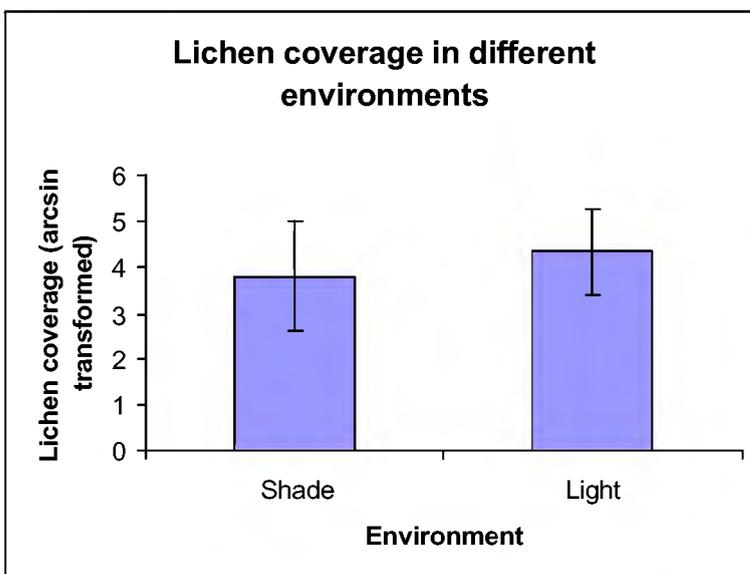


Fig 4 A comparison of the lichen coverage (arcsin transformed) in shade ( $n = 7$ ) and in open light ( $n = 3$ ).

## DISCUSSION

A previous study by Polyiam & Boonpragob (2002) suggested that the differences in microclimate at the canopy and ground level affect the growth and distribution of lichens. Another study suggested that nocturnal levels of light and relative humidity between microclimates are primary factors affecting the establishment and survivorship of lichens

(Osathanon & Boonpragob 2002). The data we collected indicated no significant difference in lichen coverage between the heights at which we measured or between the environments we sampled. However, our results are inconclusive regarding the influence of humidity or light levels on the distribution of lichens, as there was no significant difference between the microclimates at the heights or locations at which we sampled.

The validity of our data may be further questioned as the sample size was very small (we found it more difficult than expected to sample the trees); there were also methodological errors in counting lichen, as it was occasionally difficult to differentiate the lichen from tree bark.

## CONCLUSIONS

There was no significant difference in the microclimates at the heights and the locations at which we sampled. Our results are therefore inconclusive regarding the effects of humidity and environment on the growth and distribution of lichens.

We suggest repeating the experiment with a larger sample size taken at greater height intervals, and including measurement of light levels. Our study was limited by time constraints, but we suggest taking measurements of relative humidity and temperature at the same time across several days. We further suggest separating the species of trees and of lichens, and also considering the bark characteristics.

## ACKNOWLEDGEMENTS

We would like to thank all of our lecturers at IFBC 2005. In particular, we would like to acknowledge the invaluable assistance of Dr. R. Harrison, Dr. I Fang Sun, and Dr. Richard Corlett for their invaluable assistance in the construction and analysis of this project. We would like to extend a very special thanks to Pitoon Kongnoo and Preecha Phuttarak (Gai); we could not have completed our experiment without their assistance in the field.

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## **The effect of light intensity on earthworm abundance and biomass**

*Hazel Consunji, Nuansri Petcharat, & Bharath Sundaram*

### ABSTRACT

We examined the effect of light intensity on the abundance and biomass of earthworms at Khao Chong, Thailand. Earthworms are scavengers and decomposers of organic matter, and can benefit plants by making nutrients available. We sampled earthworms across five different light intensities and estimated their abundance and biomass. We correlated earthworm abundance with light intensity and found a significant relationship. We recommend that further studies use larger sample sizes, with data gathered from a wide range of light conditions, across dry and wet seasons in order to better gauge the relationship between earthworm abundance and light.

### INTRODUCTION

Earthworms are amazing animals. Way back in 50 BC Queen Cleopatra, recognising the importance of earthworms as soil aerators, declared them sacred. Charles Darwin, studying these animals in the mid-19th century, discovered that earthworms process their own weight in soil and organic matter in one day. Earthworms are scavengers: they digest dead organic matter from soils. Earthworms are, therefore, very important organisms in agricultural systems, and have been observed to increase crop yields when present. Earthworm excreta (called castings) are of economic importance due their use as a fertiliser, and earthworms are 'farmed' for this produce, called vermicompost, in many areas.

Belonging to the phylum Annelida ('segmented worms'), earthworms have a worldwide distribution with around 3000 species identified so far. They are hermaphroditic, and vary in size from a few centimetres to 3 m long. The earthworm's characteristic wriggling and burrowing movements are made possible by the contractions of two types of muscles, one set of muscles that is within a segment and another set that connects all segments. Earthworms respire through their skin and require moisture to stay alive, but cannot tolerate inundation by water.

Earthworms are no less important in rainforest ecosystems. Many evergreen trees produce leaves that are rich in tannins and secondary metabolites, and that have slow rates of natural decomposition. Additionally, most rainforest soils are infertile, with a high leaching rate due to ever-wet conditions. Earthworms, being decomposers of organic matter, deliver valuable services to plants by making nutrients available. Earthworms also change the texture of soil by increasing its water holding capacity. This service is particularly beneficial to plants in areas with sandy soils. Many factors govern the presence and abundance of earthworms within a particular area, the most important of which are soil moisture, the presence of organic matter, and light.

The objective of this study was to investigate the effect of light on earthworm abundance and biomass in a lowland dipterocarp forest at Khao Chong, Thailand.

We hypothesised that due to soil desiccation associated with high light intensity, there will be a negative relationship between the amount of light and earthworm abundance in the soil; the higher the light intensity, the fewer earthworms.

### MATERIALS AND METHODS

We sampled earthworms from five different locations differing in light intensity. At each location we extracted earthworms from three subplots of 0.5 x 0.5 m, to a depth of 10 cm. We collected all earthworms in a bag, and weighed and counted them in the laboratory. Estimates of earthworm numbers and biomass were averaged within a location. We also took light measurements at the sites, using a digital photograph of the canopy to derive a measure of light intensity by comparing shutter speeds across sites after normalising for aperture. Photographs were taken over 60 mins, and ambient light conditions across photographs were similar.



(a)

(b)

Fig 1 Earthworm sampling sites, (a) sampling in a gap, (b) closed canopy.



(a)

(b)

Fig 2 (a) Weighing earthworms in the laboratory, and (b) a sample of earthworms

We used linear regression to assess the relationship between light levels and the number and biomass of earthworms.

### RESULTS

We used the shutter speed (per 1/100 of a second) to measure the amount of light passing through the canopy. The shutter speed slows down to compensate for low light conditions.

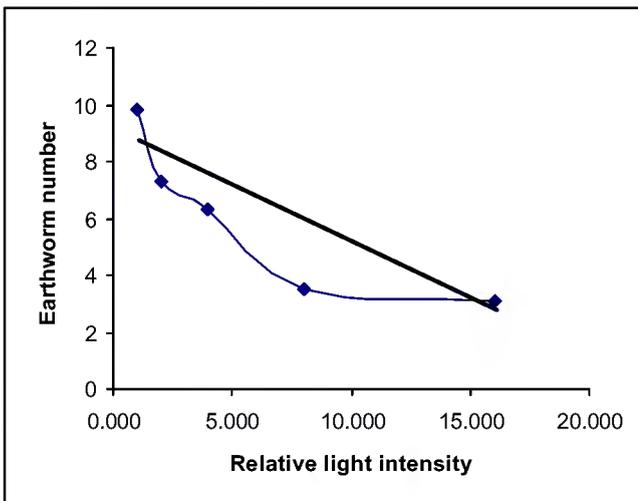


Fig 3 Linear Regression of earthworm number against relative light intensity.

As the light intensity increases, a decrease in earthworm numbers is observed ( $y = -0.3965x + 8.47$ ,  $R^2 = 0.7567$ , Fig 3).

## DISCUSSION

Earthworms have light-sensitive cells distributed in their outer skin that allow them to detect light and changes in light intensity. They also have permeable skin for breathing. This condition makes earthworms prone to drying out. They need constant moisture to stay alive. Optimum cocoon production occurs between 28% and 42% soil moisture and population densities are usually the highest between 12% and 30% soil moisture.

The most favourable temperature for most earthworms is 13-18° C. Their lower limit is 0°C, and most species do not thrive in temperatures above 22°C. Moisture and temperature are in the soil are affected by light. Direct light can also injure or kill earthworms, especially ultra-violet light.

Our results showed that there was a negative relationship between light intensity and the number of earthworms, although it was not significant. The lack of significance can be attributed to small sample sizes. Other factors that may also affect the number and biomass of earthworms like soil pH and soil type but according to studies by Darwin, earthworms can survive in a wide range of natural soil types like sand, loam, peat, silt, compost and even manure.

We recommend that tests for soil moisture should be done in order to establish direct relationships between soil moisture, light intensity and the number and biomass of earthworms. This study should also be done in the dry season to get the maximum effect of light intensity on the number and biomass of earthworms. We also recommend that sampling be done to capture natural heterogeneity that may exist in the distribution of earthworms.

## CONCLUSIONS

Earthworms need moisture in order to live. Moisture is a factor of light. The number of earthworms was negatively related to the light intensity. As predicted, at higher the light intensities, there were fewer earthworms.

## Buttress variation between trees growing on flat and inclined terrain

Sampath Wahala, Shao-chang Huang, & Liam anak Dibor

### ABSTRACT

Buttresses are a mechanical adaptation that provides support to the tree. A total of 20 trees were sampled from flat and inclined sites (10 trees in each site). At the inclined site, there was a strong correlation between buttress area and diameter at breast height. Trees at the inclined site also developed a higher total buttress area compared to flat site but the difference was not significant. At the inclined site there was no significant difference in buttress area between up- and downhill directed buttresses. Trees tend to develop more buttresses on the up hill side, but they are smaller. The findings suggest that trees can adapt very well to the terrain they are growing on. Other than buttress modifications, the trees may also make other adaptations below ground or in the crown to remain stable.

### INTRODUCTION

Large buttresses are very rare in temperate areas but very characteristic among a remarkable variety of tropical trees. Buttresses are known to occur in certain families or species of trees only. Setten (1953) reported in a survey of trees in a forest in Peninsular Malaysia that 41% of individuals of 45 cm dbh or greater had buttresses to 1.3 m or higher. A figure of 37% was found for the same tree-size and buttress-height groups in Venezuela (Rollet 1969). Eighteen out of 78 species (23 %) of trees more than 10cm dbh had buttress at Kibale in Uganda (Chapman et al. 1998), with larger size classes tending to have a higher frequency of buttressing. Rollet (1969) reported *Sloanea guianensis* and *Ceiba pentandra* to have buttresses extending to more than 7m up the tree base. Some tropical tree species are nearly always found with buttress (88% of *Intsia palembanica* trees surveyed (Setten 1953)), some rarely if ever have them (0.8% of *Callophylum*), and for the rest buttressing varies among sites and genotypes.

The juvenile tree can respond to stress by developing outgrowths between the trunk and the main lateral roots that eventually become buttress. It can also be part of its strategy or preparation to grow bigger and higher. As the tree grows from the understorey, up to the canopy, or emerges from the canopy, the potential number of occasion that a tree will experience directional stress increases. Chapman et al. (1998) predicted that understorey trees should have fewer and less developed buttresses than canopy trees, which should have fewer and less developed buttresses than emergent trees. The buttresses are part of the tree's mechanism for the efficient transmission to the ground of the stresses caused by loading due to wind (Ennos 1993). Permanent anchorage of the tree necessitates the transmission of the stresses. If not, the tree will fall down. Buttresses can probably function as both tension and compression elements depending on the direction of the wind. Crook et al. (1997) reported that the anchorage strength of buttressed trees was almost double (10.6 kNm) that of the unbuttressed ones (4.9 kNm), and the maximum moment was generated at lower angles.

Buttress roots also prevent or minimize soil erosion especially on slopes. The buttress also can accumulate the eroded soils from the higher ground. It helps to maintain the soil layer and soil fertility and therefore sustain plant growth and species diversity of an area.

If buttress formation is really for the mechanical support for the tree, then different types of stresses will result in different buttress development strategies and placing on the trunk. In this study, we studied the buttress development strategy of trees, resulted from the stresses of the topography variation, from flat to slope areas. Is there any relationship between the buttress area and diameter at breast height (dbh) or the number of buttress and dbh? Is there any difference in the occurrence of in buttresses between flat and slope areas? On slopes, are there differences in placement and buttress development on the up-hill and downhill directions?

## MATERIALS AND METHODS

### Study Sites

The study was carried out at Khao Ban Thad Wildlife Sanctuary, Trang Province, Thailand. For the slope area we found a site near to the Ton Pliw waterfall. For a flat area we surveyed the forest by the entrance of the waterfall. The sites were about 300 meters apart. The forest type was lowland wet evergreen forest.

### Methods

Sampling was done within a 5 meter-wide transect. Ten trees on the slope and 10 trees in the flat area (a total of 20 trees) were measured. We measured the girth of the trunk (gbh) (at 1.3 m from ground level or just above the buttress) and, the vertical height (VH) and horizontal length (HL) of the buttresses using a tape measure. A compass was used to determine the direction of slope and the buttress direction from the trunk. The species of trees were also recorded. Buttress area was calculated as:  $\frac{1}{2}(VL*HL)$  assuming the buttress is a triangle and the total buttress area of each tree was calculated by summing the area of each of the buttresses. Buttress orientation of an individual tree was categorized into two groups: uphill and downhill.

### Data Analysis

A two-tailed T-test was used to compare the buttress density of the two sites for any significant difference. Relationship between dbh and buttress area and the number of buttress were determined by linear regression. In the slope area the differences in buttress area and number of buttress in up hill and down hill directions were also analyzed by two-tailed T-test.

## RESULTS

Fig 1 shows that the number of buttress is increases with increasing dbh for trees growing on the slope. No relationship was found for trees growing on the flat area.

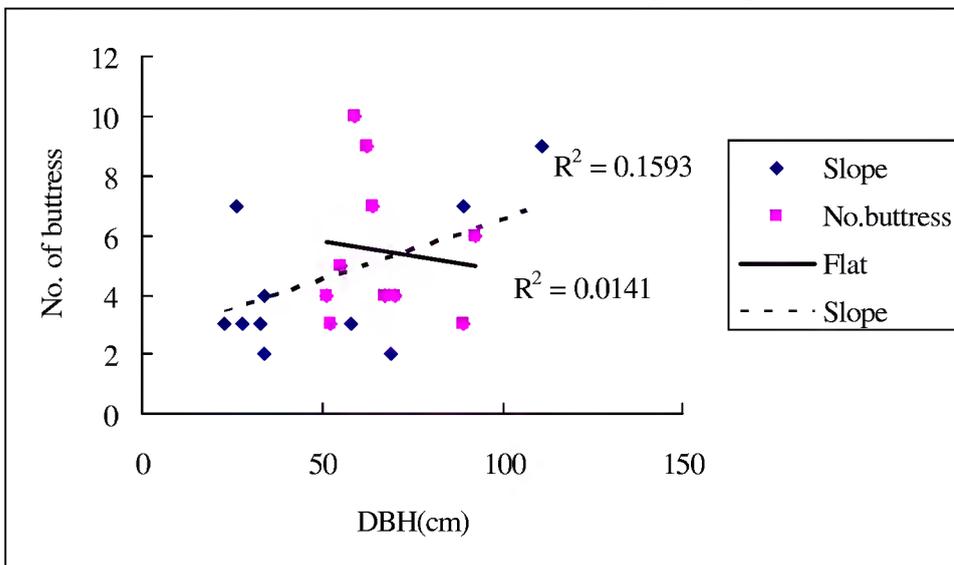


Fig 1 dbh and number of buttress in flat and slope areas.

Buttress area was no correlated with dbh in the flat area. Buttress area increased with increasing in dbh in the slope area. However, there are more smaller trees in slope area and thus there was no significant difference between site ( $p = 0.294$ )(Fig 2).

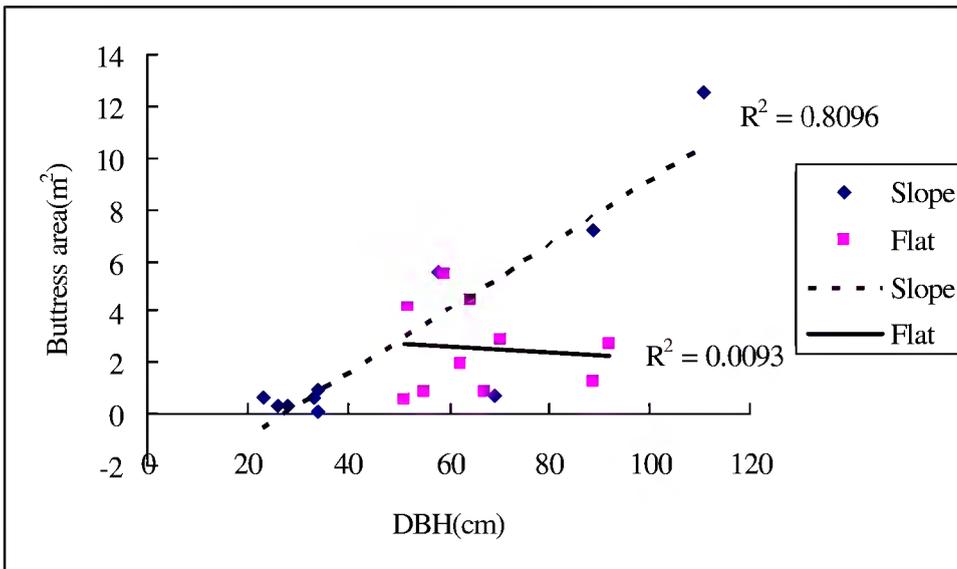


Fig 2 dbh and buttress area in flat and slope areas.

There were more buttresses in the uphill direction compared to downhill but again the difference was not significant (Fig 3).

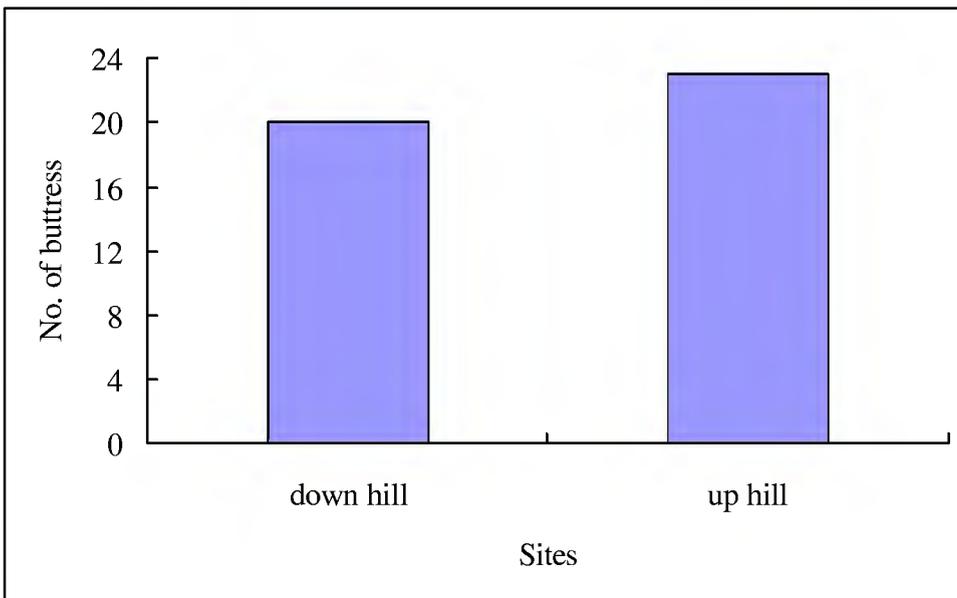


Fig 3 Number of buttress of up- and down-hill directions at the slope site

Fig 4 shows the total buttress areas of up and down hill directed buttresses of trees growing at the slope site. The total buttress area for down hill directed buttresses was slightly higher (15.18 m<sup>2</sup>) compared to up-hill directed buttresses (13.74 m<sup>2</sup>). However, the difference was not significant ( $p=0.617$ ).

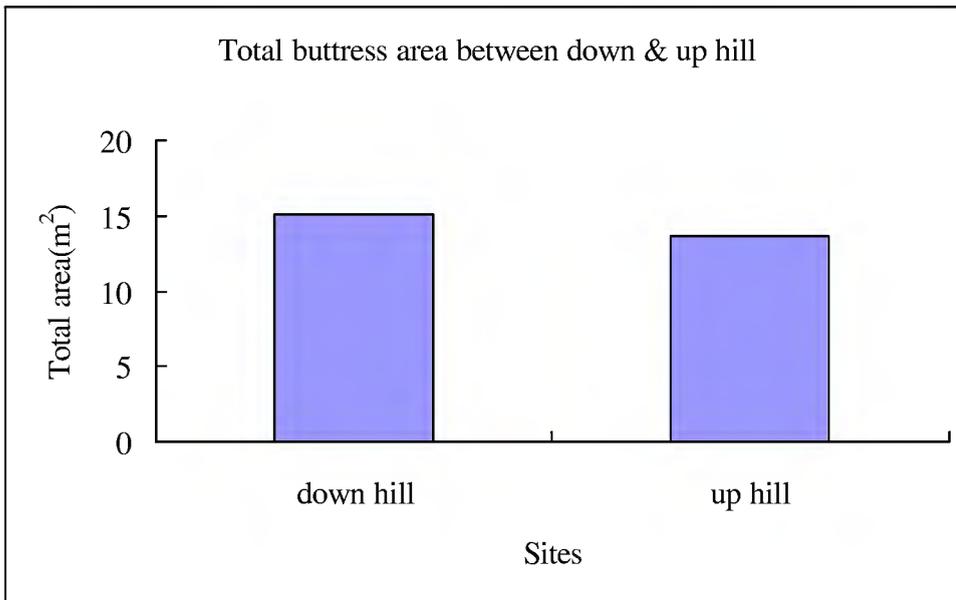


Fig 4 Buttress area of up- and down-hill directed buttress of trees at the slope site

## DISCUSSION

There was a more clear relationship between buttress area and dbh on the slope site. This may be due to a greater need for buttresses on bigger trees growing on slopes, where the ground conditions are unstable compared to flat ground.

However, there was no significant difference in buttress number or buttress area between the up- and down-hill directed buttresses in the slope area. These aboveground adaptations may also be supported by underground adaptations in root development.

The fact that the trees are growing in a dense and closed forest where the forces are “shared” or “reduced” by neighbouring trees may also affect the results. In this type of habitat, having buttresses may be an advantage to the tree, but the maximum use (in response to the maximum stress) may be rare. Comparison against trees growing on open area might produce different, interesting findings. A bigger sample size would also be preferable.

## CONCLUSION

Our original hypothesis was that trees growing on the slope would need more mechanical support because of the unstable terrain. We also hypothesized that a tree growing on a slope would develop more buttress and bigger buttresses in the uphill direction. Because we found no significant differences in buttress area or number of buttress between flat and slope areas, as well as between up- and down-hill buttresses, we conclude that the trees may have made some other adaptations and modifications in the other parts of the tree to remain balance and stable.

## ACKNOWLEDGEMENTS

We would like to extend our heartfelt gratitude to Rhett Harrison and I Fang Sun, who have made this project possible and successful.

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## Comparison of arthropod diversity on different tree barks

Dayantha Withanage, Jingmei Eunice Tan and Thanakorn Lattirasuvan

### ABSTRACT

Bark-associated arthropods were sampled from trees with three different types of bark at the Khao Chong Wildlife Sanctuary, Thailand. *Baccauria*, *Shorea* and *Syzygium* represent individuals with smooth, cracked and fissured bark type, respectively. The diversity of arthropods was found to be the highest for cracked bark, followed by smooth and then fissured bark types. The distribution of arthropods was found to be the most even on the smooth bark, followed by cracked and then fissured bark types. These trends may be the result of the heterogeneity of microhabitats within each bark type.

### INTRODUCTION

Apart from being home to bark-dwelling arthropods, tree bark may also function as highways facilitating the movement of arthropods from the ground to the canopy layer (Proctor et al. 2002). Studies have shown that little of the arthropod biomass on the bark is in the form of arthropods that live exclusively in that habitat and that a large portion of the biomass is crawling up from the soil-litter layer (Hanula and Franzreb 1998).

This study investigated the species diversity of arthropods on tree barks that vary in physical complexity. An increase in physical complexity may increase the number of microhabitats available and thus allow the support of a greater diversity of bark fauna. The distribution of all species across microhabitats has shown to be susceptible to ambient microclimate (Prinzing 2005). These microclimates are in turn influenced by the bark structure. To this end, three different textures of barks were identified for our study – smooth, cracked and fissured.

### METHODS

#### Study site

This study was performed in the Khao Ban Thad Wildlife Sanctuary, Thailand. It is located at 80-700 m altitude, with an annual rainfall of 2700 mm and mean temperature of 27°C. It experiences two seasons – the rainy season from May to January and the dry season from February to April (Leurohai and Kannika 1999).

To facilitate our study, three abundant species of trees within the sanctuary with smooth, cracked and fissured bark were chosen; *Baccauria*, *Shorea* and *Syzygium* respectively (Fig.1). Four individuals per bark type were surveyed. Trees were selected based on a diameter at breast height (DBH) of between 30-50 cm. Trees are also chosen in the same habitat so that the environmental conditions were held constant.

Upon selection of an appropriate tree, the trunk was sprayed with insecticide from the dbh mark (1.3 m) to the base of the trunk. The arthropods and displaced bark were collected using a canvas beating-sheet placed at the foot of the trunk and stored in 95% alcohol. In the laboratory, the arthropods were isolated from the bark debris, sorted and classified to family level and morpho-species.

#### Data analysis

The specimens collected for each bark type were pooled and analyzed. The Shannon's diversity index ( $H = \sum [P_i \cdot \log(P_i)]$ ) and Shannon's equitability ( $EH = H/\ln S$ ) index were calculated.



(a)

(b)

(c)

Fig 1 Tree barks of (a) *Baccauria*, (b) *Shorea* and (c) *Syzygium* used in the study.

## RESULTS

A total of 805 specimens were collected from all 12 trees sampled, comprising of the orders Hymenoptera (55%), Isoptera (41%), Coleoptera (2%), Aranea (1%), Dermoptera (0.5%), Diplopda (0.25%), Thysanura (0.25%), Neuroptera (0.12%), and Psocoptera (0.12%) (Table 1).

Table 1 Total number of Arthropod specimens collected based on taxon.

Order	Family	No. of Individuals		
		Smooth	Cracked	Fissured
Araneae	Linyphiidae	2	-	-
Araneae	Pseudoscorpions	-	-	1
Araneae	Salticidae	1	3	-
Coleoptera	Cleridae	-	5	-
Coleoptera	Coccinellidae	2	-	1
Coleoptera	Desmestidae	-	-	3
Coleoptera 1		-	-	1
Coleoptera 2		-	-	1
Coleoptera 3		-	-	1
Dermoptera	Carcinophoridae	1	1	2
Diplopda	Millipede	-	-	2
Hymenoptera	Formicidae 1	9	-	55
Hymenoptera	Formicidae 2	-	133	87
Hymenoptera	Formicidae 3	-	112	-
Hymenoptera	Formicidae 4	-	49	-
Isoptera	Termitidae	-	192	134
Isoptera 1		1	1	1
Neuroptera		-	1	-
Psocoptera		-	1	-
Thysanura	Machilidae	-	-	2
Total no. of individuals		16	498	291
Total no of species		6	10	13

The total number of individuals collected was the highest for cracked bark (498), followed by fissured (291) and smooth (16) bark (Fig 2a). The total number of species collected was the highest for fissured bark (13), followed by cracked (10) and smooth (6) bark (Fig 2b).

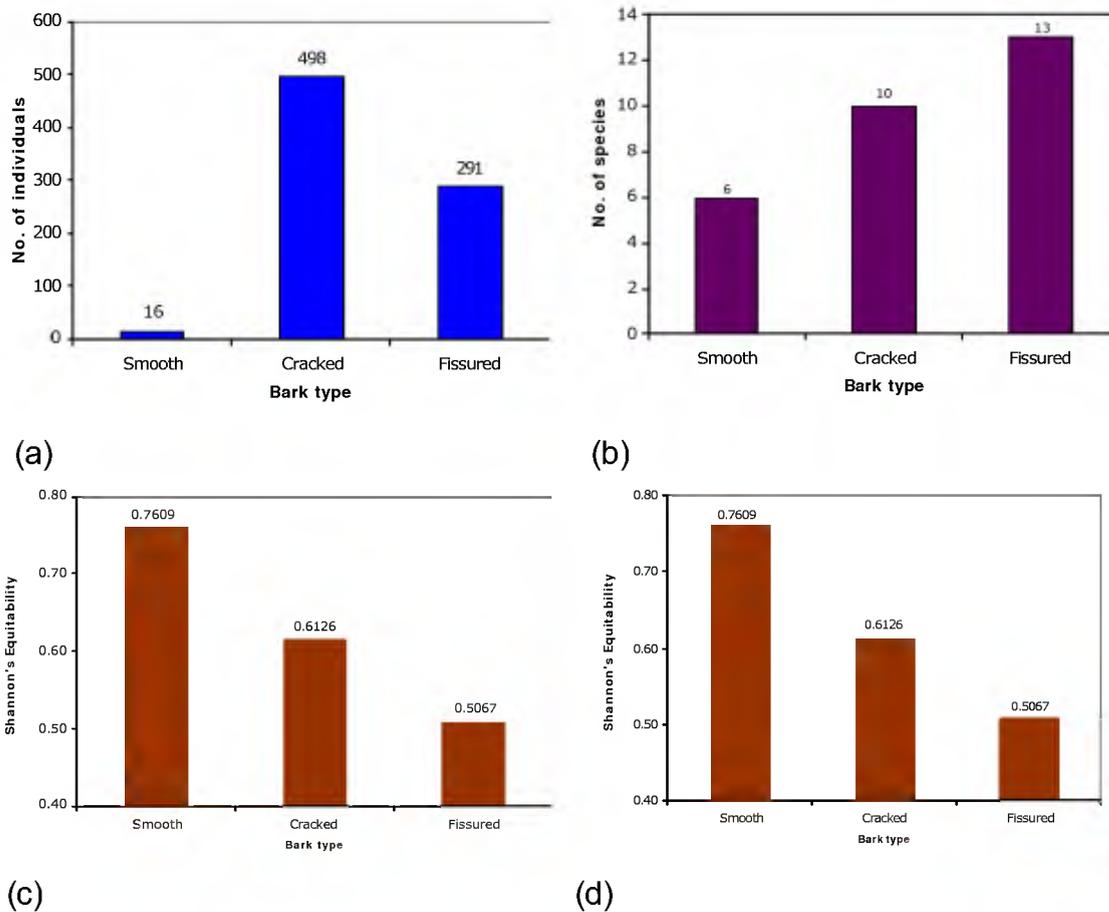


Fig 2. (a) Number of individual arthropods collected for different bark types. (b) Number of Arthropod species collected for the bark types. (c) Shannon's Diversity Index of Arthropods for the bark types. (d) Shannon's Equitability Index of arthropods for the bark types.

From our results, the diversity of cracked bark (1.41) is higher than that for smooth (1.36) and fissured (1.30) bark (Fig 2c). However, the arthropods are distributed more equitably in the smooth (0.71) bark compared to the cracked (0.61) and fissured (0.51) bark (Fig 2d).

## DISCUSSION

The arthropod distribution can be explained by the life histories of the species. For instance, sound and decayed wood, as well as bark, form part of the diet of termites. The individuals of Coleoptera found could have been bark-boring beetles which apart from feeding on the xylem or phloem, also lay their eggs in the host plant (Byers, 1995).

Despite having the greatest species richness (13), the Shannon's diversity index for fissured bark was lower than expected, because of the uneven distribution of individuals across the species collected. This is also evident from the results of the Shannon's equitability index, which is a measure of evenness distribution (0.51). The majority of the individuals collected on fissured bark were ants.

From Table 1, it is evident that Hymenoptera and Isoptera are generally abundant across the three bark types. As very few termites were recorded on smooth bark, it may indicate that termites prefer to live on rough surfaces. Fewer spiders, beetles and earwigs were found on

cracked and fissured barks. This might be the result of high abundance of ants which are efficient predators. Very few individuals were recorded from the other Arthropod orders.

Studies comparing the various bark types in subtropical forests have shown that smooth bark types have low values of insulation, while species with deep-fissured or scaly bark types have high insulation values (Nicolai 1986, 1989). Bark arthropod composition is related to bark structure. Thus, forests comprising tree species with different bark types should have a richer total bark arthropod fauna. When anthropomorphic disturbances reduce the diversity of forests and thus bark types, we can expect a reduction in specialists on richly structured bark types.

The diversity of arthropods on cracked bark was greater than that of smooth and fissured bark and the arthropod abundance distribution was found to be the most even for the smooth bark type. These observations may be explained by the individual arthropod life histories as well as the as well as the microhabitat heterogeneity of the barks.

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## Differences between the abundance of butterflies and their food plants in different habitats

*Lumyai Ittichan, M. Hasmawi Ajamain, & Sawat Sanitjan*

### ABSTRACT

This paper describes the difference between the abundance of butterflies and food plants at two sites at the top (A) and bottom (B) of the Ton Pliw Waterfall, Trang Province, Thailand. There was a significant difference in the abundance of butterflies between the sites ( $p=0.013$ ) but no significant difference ( $p=0.423$ ) in terms of the total canopy area of food plants (A: 265.1 m<sup>2</sup>; B: 365.4 m<sup>2</sup>). There were thus more butterflies per unit area of food plant canopy at A (0.15 m<sup>-2</sup>) than B (0.06 m<sup>-2</sup>). Human disturbance is a possible reason for the low abundance of butterflies in the area.

### INTRODUCTION

Lepidoptera is the scientific name given to butterflies and moths from the Greek words *lepis* meaning scales and *pteron* meaning wing. Adult butterflies spend time searching for food plants. Most butterflies have specific host plants on which they develop. However, food for adult butterflies usually consists of sweet liquid that provides needed energy sources, such as nectar from flowers. Some flowers contain more nectar, advertised by bright colors, thereby increasing their attractiveness to butterflies. We hypothesized that there would be a greater abundance of butterflies where their food plants were abundant. This study was designed to evaluate the abundance of butterflies in relation to food plants at different elevations near the Ton Pliw Waterfall, Trang Province, Thailand.

### MATERIALS AND METHODS

At each site, we used transect lines to assess the abundance of butterflies at each site. Each 200 m transect was surveyed twice. Food plants were assessed by measuring the area covered by plants that had flowers that could attract butterflies. While sampling, one of the team members spent 20 minute collecting butterflies for identification purposes.

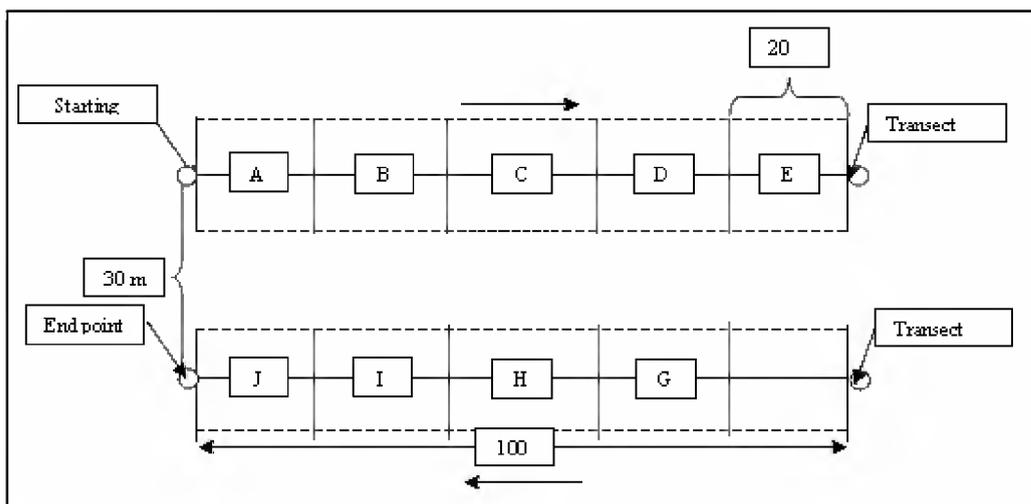


Fig 1 Transect lines

Study site

Site A (Fig 2a) was established at the top of the waterfall and site B (Fig 2b) at the lower part of waterfall. The sites were separated by 100 m.



(a)



(b)

Fig 2 (a) Site A (upper elevation), (b) Site B (lower elevation)

Data analysis

We used the independent Sample t-test to assess the difference in butterfly abundance and food plant canopy area between sites A and B.

RESULTS

Fig 3 shows a mean of 9.75 (SD 2.06) and a mean of 5.00 (SD 0.82), for the number of butterflies observed on each section of the transect at site A and site B, respectively. There was significant difference between the number of butterflies between the two sites (T-test=0.013,  $p=0.05$ )

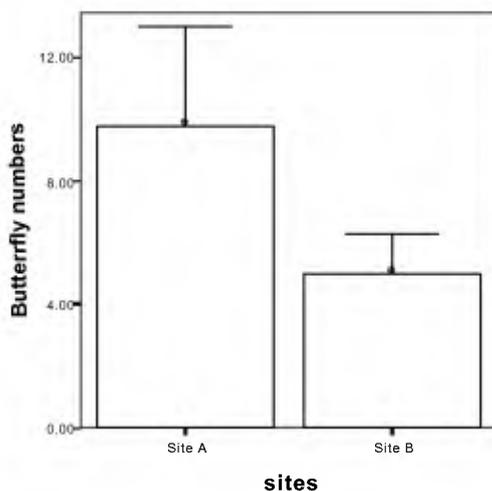


Fig 3 Distribution of butterfly abundance at Site A and Site B

Fig 4 shows a mean of 36.54 (SD 19.39) and a mean of 24.10 (SD 30.46), food plant canopy area in each section of the transects at site A and site B, respectively. There was no significant difference between the food plant area between the two sites (T-test=0.423,  $p>0.05$ ).

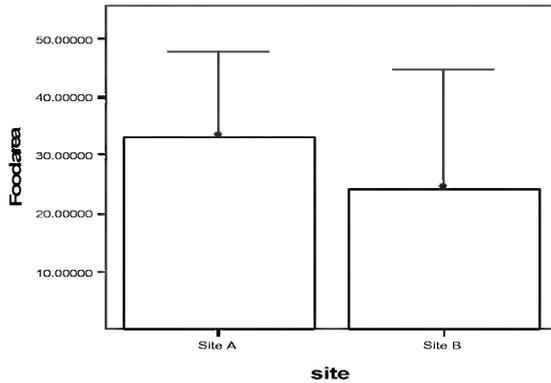


Fig 4 Distribution of food plant canopy area at Site A and Site B

### DISCUSSION

There was a significant difference in the number of butterflies between site A (upper elevation) and site B (lower elevation). Site A has almost twice the number of butterflies as site B. However, there was no significant difference in food plant canopy area between site A and site B. Therefore, we must reject our hypothesis that butterflies abundance is determined by the abundance of food plants. Butterflies can be an indicator of human disturbance. The more disturbed sites tend to have fewer butterflies. So even if there were a lot of food plants, the number of butterflies may be more influenced by the degree of human disturbance.

### CONCLUSION

The site at higher elevation by the Ton Pliw waterfall had more butterflies than at the base of the waterfall, but there was no significant difference in food plant abundant.

## Independent projects

### What kind of flower attracts stingless bees? An experiment

Chan Yoke Mui

#### ABSTRACT

Co-evolution between plants and insects brings about specialization in flower design to attract only the pollinators and exclude non-pollinators. I tested different traits that a flower might use to attract stingless bees (size, colour, smell and background colour) by using artificial flowers. I found that bees preferred big, yellow flowers with a strong smell, but background colour did not affect the preference of bees to flowers.

#### INTRODUCTION

Pollination is an important stage in the reproductive biology of Angiosperms, and insects play an important role in effecting pollination in most flowering plants (Kevan et. al 1996) by transporting pollen (male gametophyte) from anthers to stigmas and eventually fertilizing ovules (female gametophyte). Thus, for an insect to pollinate a flower, a flower must display certain properties that attract them.

The aim of this study was to find out what characteristics or properties of flowers are more attractive to stingless bees. My hypotheses were:

- H1. Larger flowers attract more bees.
- H2. Bees have specific colour preferences when foraging at flowers.
- H3. Smell is more important than colour in attracting bees.
- H4. Background colour affects the attractiveness of flowers to bees.

#### MATERIALS AND METHODS

My experiments were carried out at three locations around the main building of Khao Chong Wildlife Extension and Conservation Centre, where a colony of small stingless bees (*Trigona* sp.) was located in a nearby tree.

Honey with vanilla solution was prepared as a food reward, and coloured sponges were used as artificial flowers.

Before starting the experiment, bees were baited to the study site by putting out one or two yellow Petri dishes of honey solution at three sites, under a canopy of trees, on an open table, and near the entrance to the nature trail behind the building. The dishes were elevated on bamboo sticks hammered into ground, to reduce ant attraction. The yellow Petri dishes were prepared by pasting yellow paper to the outer bottom of the dishes. The baits were removed at least 5 minutes prior to running experiments.

Experiment 1 – Larger flowers attract more bees: A yellow sponge was cut into squares of 4 x 4 cm<sup>2</sup>, 2 x 2 cm<sup>2</sup> and 1 x 1 cm<sup>2</sup>. A teaspoon of honey solution was poured onto the sponges separated in three Petri dishes. An additional Petri dish was filled with only honey solution as a control. The dishes were laid out on the ground in a square array, approximately 0.5 m apart (Fig. 1a).

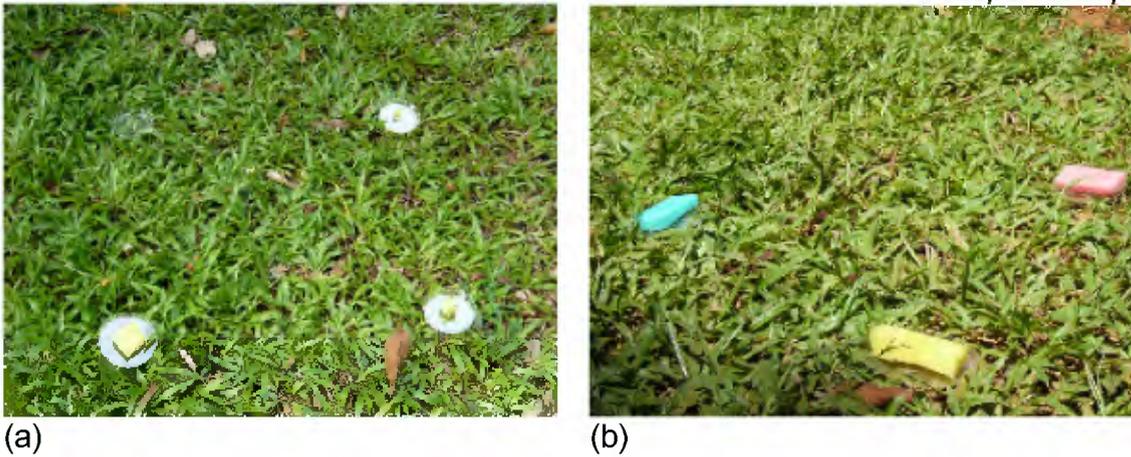


Fig. 1 (a) Experimental set up for testing the effect of different flower sizes ( $4 \times 4$ ,  $2 \times 2$ ,  $1 \times 1$  cm<sup>2</sup>) on the number of bee visits. Three Petri dishes contained an artificial flower (yellow sponge) each, and one Petri dish was without sponge as control. Honey solution was used as a reward. (b) Three different colours of sponge placed in a triangle, about 0.5 m away from one another, to test colour preference of stingless bees.

The number of bee visits to each dish was recorded for five minutes, starting from the time of the first bee landed on a sponge or dish. After every five minutes, the four dishes were rotated clockwise, until a total of 20 minutes observation was obtained. The experiment was replicated five times at each of the three different locations.

Experiment 2 – Bees have specific colour preferences when foraging at flowers: Three sponges of different colour (yellow, red and green) were cut into rectangles of  $8 \times 4$  cm<sup>2</sup> and briefly soaked in honey solution before putting them into three Petri dishes in a triangle, 0.5 m away from one another (Fig 1b). The same methodology as in Experiment 1 was applied for counting the bees, with five replicates.

Experiment 3 – Smell is more important than colour in attracting bees: Four choices were given to the bees to test which treatment was more attractive to bees:

- 1) sugar water in a transparent Petri dish (control)
- 2) sugar water + a few drops of vanilla in a transparent Petri dish (smell)
- 3) sugar water in a yellow Petri dish (colour)
- 4) sugar water + a few drops of vanilla in a yellow Petri dish (smell x colour)

Bees were counted the same way as in Experiment 1, with 3 replicates

Experiment 4 – Background colour affects the attractiveness of flowers to bees: Green and white paper of 15 cm x 21 cm were used as background colour. Two  $4 \times 4$  cm<sup>2</sup> yellow sponges were placed in separate Petri dishes with different background colours. Each dish was placed 0.5 m away from the other. Bees were counted using the same methodology as in Experiment 1, with 4 replicates.

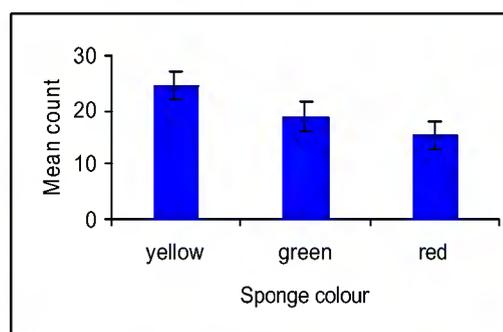
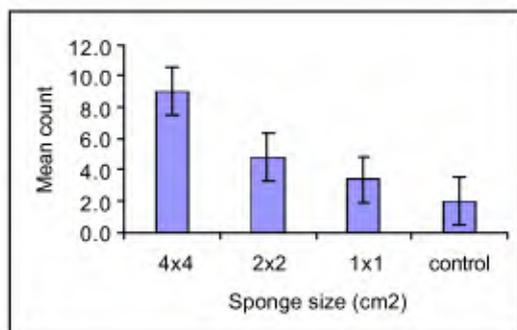
#### Data analysis

The proportion of bees visiting each treatment in each replicate was calculated. All data were arcsine transformed for normality before performing one-way ANOVA and multivariate ANOVA (Experiment 4). Post-hoc tests were carried out using LSD analyses.

## RESULTS

For the first two days of experiment, only one species of *Trigona* bees were attracted to the baits that I set up. On the final day, however, there was another bee species (*Apis*) came to one the bait located near the entrance of the nature trail. In order to avoid bias on species' preference, the *Apis* bees were not counted in this experiment.

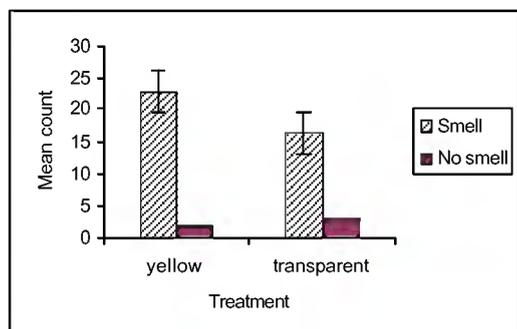
Results from one-way ANOVA analysis of Experiment 1 showed a highly significance effect of sponge size ( $F_{3,16} = 7.14, p=0.003$ ; post-hoc comparisons of means  $4 \times 4 > 2 \times 2 = 1 \times 1 = \text{control}$  at  $p < 0.05$ ), where the biggest sponge attracted more bees (Fig 2a). The effect of colour (Experiment 2) was also highly significant ( $F_{2,12} = 17.59, p < 0.0001$ ), where yellow colour attracted the bees (post-hoc comparisons of means yellow  $>$  green = red at  $p < 0.05$ ) (Fig 2b). Thus, hypotheses 1 and 2 were accepted.



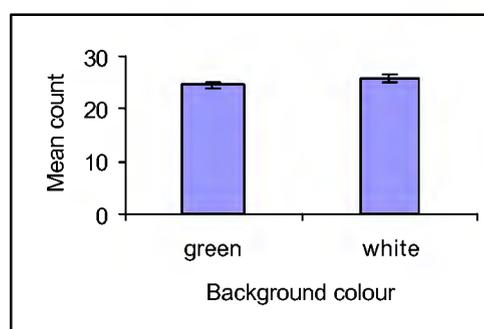
(a)

(b)

Fig 2 (a) Total number of bee visitations for different sponge size (n replicates = 5). The control had no sponge but only honey solution. Error bars = s.e. of means, (b) Total number of bee visitations for different sponge colour (n replicates = 5). Error bars = s.e. of means



(a)



(b)

Fig 3 (a) Total number of bee visitations for four different treatments with two main factors; colour and smell (n replicates = 4). Error bars = s.e. of means, (b) Total number of bee visitations for yellow sponge in different background colour (n replicates = 3). Error bars = s.e. of means.

Multivariate ANOVA was used to test the effect of smell and colour in Experiment 3. The overall model was highly significant ( $F_{3,12} = 15.07, p < 0.001$ ). Smell has the greater effect than colour, while the interaction between colour and smell was not significant (Fig 3a, Table 1). Thus, Hypothesis 3 was accepted.

Table 1 Multivariate ANOVA table for effects of colour and smell in attractiveness to bees ( $F_{3,12} = 15.07, p < 0.001$ )

Source	DF	Sum of Squares	F Ratio	Prob > F
colour	1	0.06125625	4.7524	0.0499
smell	1	0.49350625	38.2872	<.0001
colour*smell	1	0.02805625	2.1767	0.1659

There was no significant difference in the number of bees attracted to either green (mean  $n = 24.7$ ) or white background (mean  $n = 26.0$ ) (Fig 3b). Thus, Hypothesis 4 was rejected.

## DISCUSSION

A bigger flower has a larger display area, making it is easier to detect by a bee and thus reducing the bee's search time. Bigger flowers also suggest that it has more rewards compared to a smaller flower. Honey bees detect large flowers using colour contrast but detect smaller flowers using green contrast. Kevan et. al (2001) and Spaethe et. al (2001) suggest that bees favour colour contrast over green contrast in detecting large flowers, because the former uses three receptors input compared to only one for the latter, which gives a more reliable identification of flowers. Bees face difficulties in detecting a flower if colour contrast is absent. My experiments also indicated that the largest flower was more attractive, but smaller flowers were not significantly more attractive than the control.

For most insects, colour is important in flower detection and recognition (Kevan et. al 1996), and different colours might attract different insects. Numerous studies on colour vision of honeybees have been made (Giurfa et. al 1995, Spaethe 2001, Rodriguez-Girones & Santamaria 2004). Honeybees have trichromatic vision based on ultraviolet, blue and green photoreceptors (Kevan et. al 2001). Giurfa et. al (1995) showed that *Apis mellifera* has colour preferences for bee-blue (blue to human) and bee-green (yellow to human), and the colour choices of bees strongly correlate with nectar production of flowers of different colours. My experiments showed that *Trigona* sp. stingless bees preferred yellow artificial flowers the most, which is consistent with the results from honeybees. Red was least visited by bees. Honeybees have difficulties in separating red from green (Spaethe et. al 2001) and in my experiment there was no significant difference between red and green treatments.

Smell had a stronger effect on bees visitation compared to colour, suggesting that these bees prefer smell over colour in selecting flowers at short range. In fact, Giurfa et. al (1995) have shown that colour can not attract a naïve honeybee to flowers without odour. Strong smell probably is more reliable in flower identification as it possibly more closely correlated to the reward available to the foragers.

White and green backgrounds did not affect the number of visits by bees. Either both colours give the same level of colour contrast, or the bees just ignore the background colour when the smell and colour of the flower is strong enough to attract them. Although white background is more obvious in terms of brightness to humans, this is not so for honeybees as they do not have a perception of brightness (Kevan et. al 2001).

## CONCLUSIONS

Stingless bees (*Trigona* sp) were most attracted to big, yellow artificial flowers with a strong smell (vanilla). Therefore, we should expect stingless bee-pollinated flowers to have big bright yellow petals, and produce a strong fragrance.

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## Foraging Distance in the Stingless Bee *Trigona thoracica*

Sampath Wahala & Pien Huang

### ABSTRACT

The foraging patterns of stingless bees are dependent on resource availability. Human alterations to natural areas will affect the condition of local habitats, and influence the bees' foraging behavior. In this study, we assessed the familiarity of *Trigona thoracica* with two distinct habitats. We found that *T. thoracica* foraged further into the densely wooded habitat (3.676 km) than in the altered, semi-natural habitat (1.973 km), indicating a preference for the forested environment.

### INTRODUCTION

The activity of stingless bees is informed by the availability of resources, which is highly dependent on the quality and composition of the surrounding environment. While many stingless bee species are capable of building their nests in artificial habitats, for most species these habitats must be surrounded by intact forests to sustain the foraging process (Heard 1996). In gaining familiarity with an area, bees will form a simple spatial map with stored landmarks. This geocentric navigation tool serves as a secondary system to the bee's egocentric ability to utilize the location of the sun to determine directionality on a trip-by-trip basis (Dyer 1996). A combination of egocentric and geocentric methods allows bees to successfully navigate through various landscapes (Wehner 1996).

This study investigates the familiarity of the stingless bee *Trigona thoracica* with two distinct habitats. It has the dual purpose of comparing foraging distance between the intact forest and disturbed environments, and of evaluating the idea that bees create memory patterns for navigational purposes en route to destinations. We hypothesized that bees forage more frequently in the natural environment than in the disturbed environment, and are therefore more familiar with forested terrain. We also suspected that bees are able to form a visual memory in transport, and that they will integrate cues they acquire in transition to guide themselves home from unfamiliar locations.

### MATERIALS & METHODS

#### Colony Selection

We selected a (medium-sized) colony of *Trigona thoracica* at the base of a *Ficus microcarpa* tree near the entrance to the Khao Chong Peninsular Botanic Gardens. The nest was located in a relatively open area, adjacent to two distinct environments: a densely wooded forest to the east and an altered, semi-natural environment along a highway to the west. One transect line was placed in each of these two areas, and three release points along the transects were determined using a GPS (East – Forest area: 350, 650, 1200m; West - Highway: 400, 800, 1200m).

#### Sampling Methods

Outgoing bees were collected in plastic bags and tagged with paint markers. Groups ranging in size from sixteen to seventy bees were then transported in an insect cage to designated release points either on foot or by motorbike. At each location, two samples (covered and uncovered) were released at staggered times. The two transects were completed over the course of three days, with a total of twelve releases. On each day we had similar sunny and dry weather conditions.

## Data Collection

On each day, the nest was observed from the first release to at least 1.25 hrs after the last release; the activity of marked bees (entering or exiting the hive) was recorded, as well as the time of that activity. We completed a total of twenty hours of observation.

## Data Analysis

Percentage returns were calculated for each batch of marked bees released from each of the three releasing points on each transect, according to the recorded number of returns for each batch.

Paired T-Tests were conducted to compare the arcsin transformed values of covered and uncovered returns within each transect and between transects, and also the total returns between two transects.

Maximum forage distances into different environments were calculated using linear regression of percentage returns of total bees and distance from the colony for both transects.

## RESULTS

The percentage returns of bees released from three releasing points on each transect are given in Tables 1 and 2.

Table 1 Percentage returns of stingless bees, released along the East transect (Forest habitat)

Distance from the colony (m)	No. Returned		No. Returned		% Returned	
	Covered	Uncovered	Covered	Uncovered	Covered	Uncovered
350	29	40	6	11	20.69	27.50
650	32	19	5	6	15.63	31.58
1200	50	32	8	7	16.00	21.88

Table 2 Percentage returns of stingless bees, released along the West transect (Disturbed habitat)

Distance from the colony (m)	No. Returned		No. Returned		% Returned	
	Covered	Uncovered	Covered	Uncovered	Covered	Uncovered
400	42	20	6	51	14.29	25.00
800	29	16	3	4	10.34	25.00
1200	70	26	5	3	7.14	11.54

According to the paired t-test, there was no significant difference in the returns between uncovered bees and covered bees on the East transect ( $t = -2.9507$ ,  $p = 0.00982$ ), or West transect ( $t = -3.2981$ ,  $p = 0.809$ ).

Percentage returns of all stingless bees (covered and uncovered) released along the both transects are shown in Fig 1.

Maximum forage distances in both environments were calculated using linear regression.

- Regression equation for the East transect

$$y = -0.0073x + 26.837 \quad (R^2 = 0.9779)$$

Calculated maximum forage distance in forested habitat = 3676m

- Regression equation for the West transect

$$y = -0.0118x + 23.286 \quad (R^2 = 0.9128)$$

Calculated maximum forage distance in the disturbed habitat = 1973m

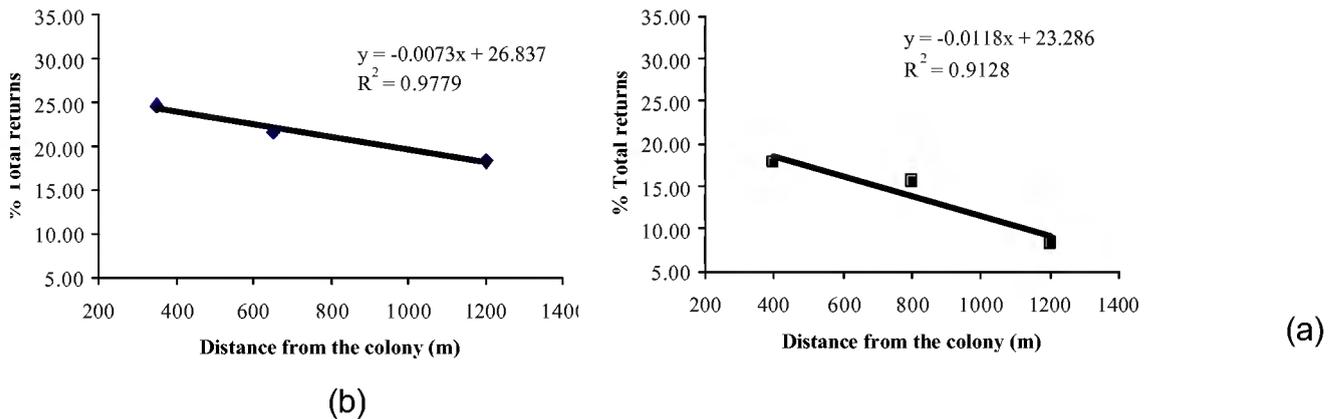


Fig 1 (a) Percentage returns of all stingless bees released along the East transect, (b) percentage returns of all stingless bees released along the West transect

## DISCUSSION

Our results showed decreasing returns of bees as a function of distance. This is a logical relationship that indicates that bees are more familiar with the territory closer to their nests.

There was no significant difference between the number of covered and uncovered bees that returned. This leads us to believe that the bees do not form memory when they are artificially transported, which may be due to factors which differ between artificial transport and normal flight behavior. Possible factors include the rate of movement and the height of travel. Additionally, the mesh-and-plastic carrying cage may have skewed the bee's exposure to sunlight and added an abnormal level of stress for the bee, altering the bee's ability to assess the solar pattern. These factors would contribute to the bee's incapacity to use egocentric methods for homeward navigation.

As expected, there was a difference in the foraging distance according to habitat; at each distance a higher proportion of bees returned from the forest habitat than from the disturbed environment. While our estimated maximum foraging distance in the disturbed environment falls within the range of previously calculated distances traveled by stingless bees in the Neotropics (*Cephalotrigona capitata*: 1.5 km, *Melipona panamica*: 2.1 km, Roubik 1979), our estimate of maximum foraging distance (3.676 km) in the forest was much higher. It is possible that the difference in genera and species can account for this difference in foraging distance. *T. thoracica* is the largest Asian stingless bee.

## CONCLUSIONS

We found that the bees are more familiar with the natural habitat than the disturbed habitat. The forage distance was determined to be 3.676 km in the forested area and 1.973 km along the highway. Our data suggests that there may be harmful effects on bee populations as a result of human development, resulting from habitat conversion and fragmentation. These implications warrant further exploration. We suggest replicating this study on the same bee colony using transects perpendicular to the ones we took, as there were diverse environments in those directions. We also suggest conducting a longer study with a larger, multi-colony sample size.

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## Predatory behavior of antlions

Chen Po Hao & Samangi Hewage

### ABSTRACT

Different sizes of antlions make different sizes of pits, so their ability to catch prey of different sizes varies with their size. Selected antlions were maintained under laboratory conditions and allowed to make their pit in a plastic cup of sand. They were then starved for different lengths of time, and afterwards fed with three different species of insects. We recorded the time spent to catch and kill the prey. Each antlion was used for single a observation. Larger antlions selected prey according to their level of starvation but smaller antlions attacked all the sizes of prey, although they only successfully caught smaller prey.

### INTRODUCTION

Antlions belong to the order Neuroptera, class Insecta. They belong to the family Myrmeleontidae. This name is rooted in the Greek words myrmex (ant) and leon (lion). The antlion name is applied to the larval stage. ([www.antlionpit.com/what.html](http://www.antlionpit.com/what.html)). Adult insects of this family have four lace-like wings, similar to dragon flies.

Different antlion species have different predatory behavior. Pit building behavior is characteristic of the genus *Myrmelon* (Napolitano 1998). They build a pit in dry sand using an oval, bristled abdomen and then buried themselves, leaving their powerful jaws uncovered. They consume other insects, especially ants. Ants are the most common insect found in dry sand where the antlions build their pitfalls.

Antlions come in different sizes and they appeared to consume different prey according to preliminary observations we made. Hence we wished to establish whether antlions have the ability to select their prey, and whether their level of hunger and their own body size affect prey selection.

### MATERIALS AND METHODS

#### Study site

Present study was conducted in Khao Chong Wildlife Extension and Conservation Center, Trang Province, Thailand. We conducted two laboratory experiments.

#### Experiment 1: Identification of the predatory behavior of antlions

In order to identify the predatory behavior of antlions, we collected antlions from the field and kept them in containers filled with dry sand. They were kept for about six hours for rest and recuperation, and allowed to make their pit, before they were fed with prey. The experiment was conducted at room temperature.

Each antlion was given an ant. The ant was dropped in the center of the pit and resulting interactions were observed. Ants were given repeatedly until the antlions no longer attacked the ants. Observation of the antlion was started as soon as prey dropped in the center of the pit and ended with either the prey dead or escaped from the pit.

#### Experiment 2: Effect of antlion size, starvation level, and prey size on the predatory behavior of antlions

Our hypothesis was that antlions select their prey according to the prey size, starvation level and their own size. Antlions were collected from a population near the laboratory and categorized into two groups according to body size (0.5-1 cm long and <0.5 cm long). Total length of the antlion was considered for this study. Both size classes were sub-divided in to four groups of 15 individuals, and they were fed with ants. After feeding each group was starved for

a different length of time (0 hrs (level 0), 12 hrs (level 1), 24 hrs (level 2), and 36 hrs (level 3)), before commencing the feeding experiment.

Table 1 Species, length and category of the prey selected for this study

Species	Length, mm	Category
<i>Camponotus</i> sp.	12.0	Ants
<i>Macrotermes carbonarius</i>	7.0	Black termites
<i>Acropyga</i> sp	3.0	Ants

Each antlion was used for only one observation. The time taken to catch and kill the prey was recorded for each individual antlion.

#### Data analysis

From the collected data predatory success for small and large antlions was calculated for each treatment (starvation level \* prey type) using the equation:

$$\text{Predatory success} = \frac{\text{Number of antlions that attacked and consumed the prey}}{\text{Total number of antlions}} * 100$$

#### RESULTS

Predatory success for small antlions and large antlions at each starvation level was plotted (Fig 1 and 2)

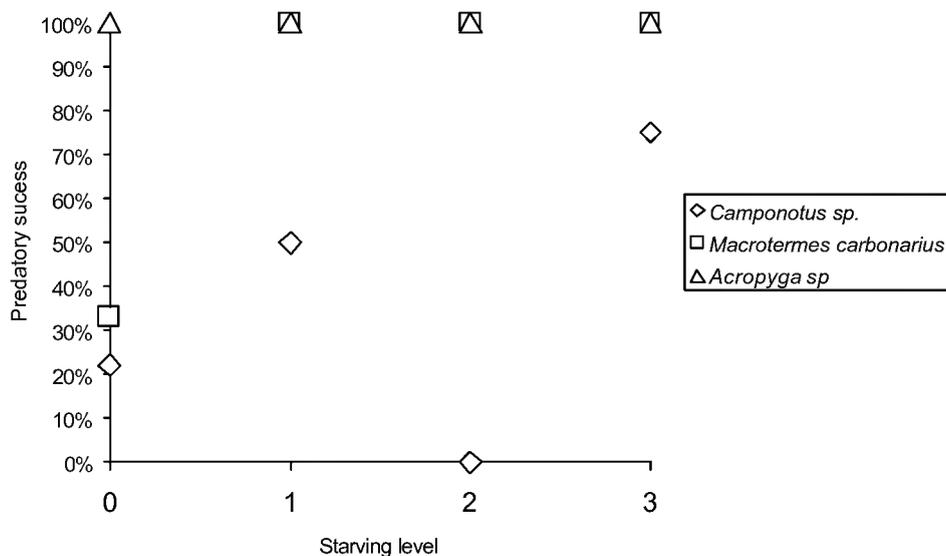


Fig 1 Predatory success of large antlions at different starvation levels.

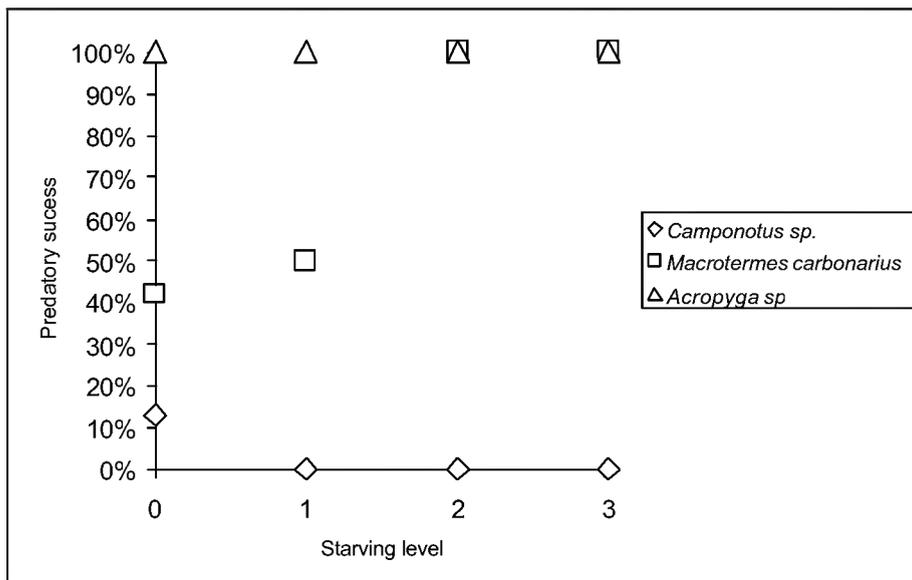


Fig 2 Predatory success for small antlions at different starvation levels

One sample T – tests were run in order to check whether there was a significant difference in predatory success between three types of prey at the same starvation level (Table 2).

Table 2 *P* values of one sample T – test for the significance of prey size at each starvation level (Fig 1 & 2)

(A) Large antlions

Starvation level	<i>P</i> - value
0	0.1681
1	0.0377
2	0.1835
3	0.0082

(B) Small antlions

Starvation level	<i>P</i> - value
0	0.1808
1	0.2254
2	0.1835
3	0.4226

In order to identify the relationship between predatory action and starving level for small antlions and large antlions a contingency analysis was conducted. Predatory actions were divided in to two groups, attacked and not attacked. There were significant differences in predatory action among starvation levels for large antlions, but not in small antlions (Table 3).

In order to identify the predatory action by prey type a second contingent analysis was carried out (Table 4). Large antlions always attacked small prey and attacked large prey less frequently, but small antlions attack all prey with equal frequency.

Table 3 Predatory action against starvation level for small and large antlions.

Starving level	Predatory action (%)	
	Large antlions	Small antlions
0	72.73	81.4
1	91.67	100
2	77.78	100
3	100	100

Large:  $P=0.0005$  Chi square= 15.140 DF= 3  
Small:  $P=0.3020$  Chi square= 0.3554 DF= 3

Table 4 predatory action against prey type for small and large antlions.

Prey type	Predatory action (%)	
	Large antlions	Small antlions
<i>Camponotus</i> sp.	69.57	86.96
<i>Macrotermes carbonarius</i>	69.23	85.71
<i>Acropyga</i> sp.	100	96.43

Large:  $P=0.0149$  Chi square= 10.483 DF= 3  
Small:  $P=0.057$  Chi square= 7.521 DF= 3

A one way analysis of variance was conducted to investigate the effect of prey size on handling time for two different sizes of antlions (Table 5).

Table 5 ANOVA results for the effect of prey size on handling time for two sizes of antlion.

Test	DF	F value	Mean sq	P - value
Large antlions	2	12.59	855243.2	0.00004
Small ant lions	2	36.57943	902252.2	$1.7 * 10^{-9}$

## DISCUSSION

Two main operations were observed in the predatory behavior of antlions; attacking and killing prey. Between catching the prey and death of the prey, there are several other behaviors involved. All these are interconnected and there are no clear margins to differentiate them. When the prey falls in to the pit, the antlion rapidly expels sand from the pit to cause the prey to slide further into the pit. Then the antlion tightly holds the prey using its mandibles and tries to pull the prey down into the pit until it is part buried in the sand. Finally the antlion emerges from the pit holding the prey and drums the prey by flicking its head until of the prey dies.

According to our results larger antlions attack more large prey as starvation level increased (Table 2), but small antlions try to attack all prey without regard to size. However, predatory success was low for small antlions, when they attacked larger prey. Smaller antlions may be less experienced in assessing prey size or likelihood of success.

We found the selected time scale for the starvation levels was too long. Hence, it was difficult to compare the predatory success of different starvation levels. A future experiment could be conducted using shorter periods.

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We would like to express our sincere gratitude to Dr. Rhett Harison, Dr. David Lohman and Ms. Luan for their encouragement and help given to us to make this project a success. We wish to give our sincere thanks to our colleagues for there moral support. At the last, we want to say sorry to ants, termites and antlions for destroying their colonies and habits. We hope that the damage caused can be recovered.

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## Food preferences of small mammals in a moist evergreen rain forest

Liam anak Dibor & Nuanseri Petcharat

### ABSTRACT

Results of studies on the preferences of small mammal for different baits and food patches sizes are presented. Over a 72 hour trapping period, a total of the 27 individuals representing 4 species of small mammals (2 rat spp, Common tree shrew and Moonrat) were captured. Overall results found that there were no significant preferences for particular baits. The results also showed that there was no significant difference among small mammal species in bait preferences. There was also no significant difference in the relative proportion of bait removed from small and large food patches, which suggest that there is no strong selection pressure from small mammals on fruit source sizes.

### INTRODUCTION

Khao Ban Thad Wildlife Sanctuary covers an area of approximately 480 ha. It was established in 1971 to protect the watershed of several rivers and to conserve the moist evergreen rain forest, which is the habitat of a diverse community of flora and fauna.

Thailand has a total of 265 species of known extant mammals as of 2002. Small mammal distribution and richness varies between habitats. Tuen *et al.* (2002) reported a capture of 35 individuals representing 15 species of small mammals at Crocker Range Park, Sabah, Malaysia, at elevation of 800 – 1070 m. The capture rate for rodents and shrews was 0.08 animal/trap-day. Simrad and Fryxell (2003) compared small mammals diversity between “disturbed” (~30 years since logged) and “protected” (~90 years since logged) forests, and reported that protected stands produced significantly higher densities of seeds and supported a more diverse group of small mammals. Increased family richness of terrestrial arthropods was also detected within the protected stands. The findings indicated that disturbed stands have lower levels of seed production with consequent effects on the diversity and abundance of small mammals and arthropods.

The objectives of our study were to compare the food preferences among small mammals and to compare their preference between small and large food patches.

### MATERIALS AND METHODS

#### Study site

The study was conducted at Khao Chong Wildlife Extension and Conservation Promotion Center, Trang Province, Thailand. The study area is a secondary lowland moist evergreen forest. The elevation ranged from 500 – 700 m. It was logged over 30 years ago.

#### Methods

Four local mousetraps (in two sizes: 18 x 18 x 37 cm and 12 x 14 x 30 cm) baited with banana, rambutan, corn and cake were placed close to each other at each trap site. A total of forty traps in ten locations were placed at least 20 meter apart on the ground and on branches along winding jungle trails. The traps were checked between 8-10 am in the morning and 4-6 pm in the afternoon. Successful traps were washed, rebaited and put back on the same spot after the animal was removed. All animals were identified and in addition photographs were taken before being release.

One by one meter open plots were also established. Litter was removed and five different foods (banana, rambutan, corn, cake and peanut) were placed in the plot. A total of ten plots were established, at least 10 meters away from a trap location. The plots were checked

### Independent projects

between 8-10 am in the morning and 4-6 pm in the afternoon. The experiments were conducted over three trap nights, from July 8-10, 2005.

To study the preference for small or large food patches, we established removal plots of 10 and 50 slices of the most preferred food, banana. The plots were at least 20 meters apart. The slices were arranged in a 10 cm grid. The experiment was repeated in five replicates and was monitored for 2 days (afternoon, 10 July to morning, 12 July).

### Data Analysis

Chi-square analyses were performed to determine significance differences in capture with different bait types. A paired T-test was performed to compare the relative proportion removed between small and large food patches.

### RESULTS

The number of captures for each bait type is presented in Table 1. There were a total of 35 small mammals caught, including eight incidents in which bait was taken but the animal was not caught. Cakes were eaten on twelve different occasions, followed close by banana. However, the Chi-square analysis revealed that there was no significant preference for particular baits.

Table 1 Bait and number of times bait was taken by small mammals.

Species	Bait and # of times bait was taken				Total
	Banana	Rambutan	Corn	Cake	
<i>Rattus</i> sp. 1 (Rat)	1	1	2	1	5
<i>Rattus</i> sp. 2 (Rat)	1	3	1	4	9
<i>Echinosorex gymmurus</i> (Moonrat)	0	0	1	2	3
<i>Tupaia glis</i> (Common treeshrew)	9	0	0	1	10
Bait taken, no capture	0	1	3	4	8
Total	11	5	7	12	35

The number of times each type of bait was taken in the removal plots is presented in Table 2. The Chi-square analysis revealed that there was no significant difference in bait preference among the species.

Table 2 Number of times each type of bait was taken.

Bait	# of times bait was taken
Banana	18
Rambutan	14
Corn	16
Cake	18
Peanut	17
Total	83

Chi-square=0.675, df=4, Sig.=0.954

A paired T-test result showed that there was no difference in relative proportion of bait removed from small and large food patches (Table 3).

### DISCUSSION

A total of 27 individuals representing four species of small mammals were captured during this study. This small number of species, however, does not necessary mean that Khao Chong is

depauperate. It may simply reflect the limitation in time and coverage of the study area. Capture rate data is a useful indication of the relative abundance of animals. The capture rate was 0.30 animal/trap-day (30% trap success), which is very high.

Table 3 Relative proportion removed between each food patch.

Food Patch	Relative Proportion Removed				
	1	2	3	4	5
Small (10 pcs.)	7/10	10/10	2/10	3/10	10/10
Large (50 pcs.)	5/50	12/50	19/50	2/50	18/50

$t = -1.366$ ,  $df = 4$ , Sig. (2-tailed) = 0.244

Rats showed no food preference. They took all types of food in almost equal proportions. Moonrat ate corn and cake, which are "alien" to the natural environment. The Common tree shrew ate banana most of the time. They also represented the highest number of captures in this study. Small mammals may also eat insects and buds.

Results from the food patch size experiment, suggests that small mammal foraging patterns are not affected by the patch size. It is possible they encounter patches by chance, and so patch size has little influence. Fedriani (2004) reported a similar scenario that there is no simple relationship found between mouse abundance (as estimated by trapping success) and strength of fruit predation. None of the measured plant phenotypic traits (e.g., number of fruit or plant size) had a significant effect on mouse foraging. Conversely, environmental traits (substrate and distance to nearest tree) influenced fruit predation by mice. His findings support the initial hypothesis that the net outcomes of the interaction between plant (*Helleborus foetidus*) and mice in southern Spain may not have strong coevolutionary consequences. Our results suggest that the situation may be similar in Khao Chong.

## CONCLUSION

We did not find any significant preferences among small mammals for different types of bait. The results also did not support our second hypothesis that small mammals will be more attracted to larger food patches.

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## Pollination and parasitism in some fig species

Warin Wannaprapho & Tan Jingmei Eunice

### ABSTRACT

Being seed predators the interaction between fig wasps and figs ranges from mutualism to parasitism. We studied the fig pollinator mutualism and parasitism in six species of figs. Our observations suggest that (i) non-pollinators do not express preferences for fruits at particular heights; (ii) for some species, the number of foundresses was found to correlate with the number of seed and bunch size, as well as the fruit size. The association of flower development with increased numbers of foundresses per fruit, suggests that flower development within a fruit may be limited by pollen availability. The correlation between the number of fruits and foundresses may imply that the presence of a larger crop of inflorescences is more successful at attracting wasps.

### INTRODUCTION

The family Agaonidae (Hymenoptera: Chalcidoidea) includes hundreds of non-pollinator wasp species that are closely associated with fig inflorescences (Wiebes 1979). An enclosed receptacle, this inflorescence is characteristic of the genus *Ficus* (Moraceae). Fertilization of fig flowers by pollinators is mutually beneficial for both the wasp and the fig, as this is also the food resource for the next generation of wasps (Weiblen and Bush 2002). The patterns of viable seed and wasp production profoundly affect the reproductive success of both fig and pollinator wasps and thus lie at the centre of the mutualism (Bronstein 1991). Studies have shown the negative impact of non-pollinators on pollinator population dynamics through the predation of pollinator larvae and competition for seed resources (Kerdelhué and Rasplus 1996; Kobbi et al. 1996).

In this study, we investigated the relationship between the abundance of non-pollinators with respect to the position of the inflorescence in three species of fig. Our hypothesis was that the presence of predators, such as ants and spiders, on or near the ground would reduce non-pollinator numbers lower on the tree. We also examined the relationship between foundress numbers and seed production in six species of figs, in order to determine the pollination success.

### METHODS

Trees belonging to the genus *Ficus* were identified within the Khao Ban Thad Wildlife Sanctuary, Thailand. Khao Ban Thad is located 80-700 msl, with an annual rainfall of 2700 mm and mean temperature of 27°C. It experiences two seasons – the rainy season from May to January and the dry season from February to April (Leurohai and Kannika 1999) In total, 16 fruiting fig trees representing six species – *F. cocinna*, *F. fistulosa*, *F. hispida*, *F. schwarzii*, *F. scortchtenii*, and *F. semicordata* were used in this study (Fig 1). The height of the fruit crops and the bunch size were recorded. This was to attempt to take into account all variables that might affect the results observed. The presence of other fauna such as ants and spiders that might prey on the fig wasps was also noted. A total of 179 fruits were collected.

The diameter of the fruits, the number of seeds within each fruit, as well as the number of foundresses present in each fruit was recorded. Male fruits from three trees - *F. fistulosa*, *F. hispida* and *F. schwarzii* had wasps emerging from them. The wasps were collected and identified to the genus level (Fig 2).

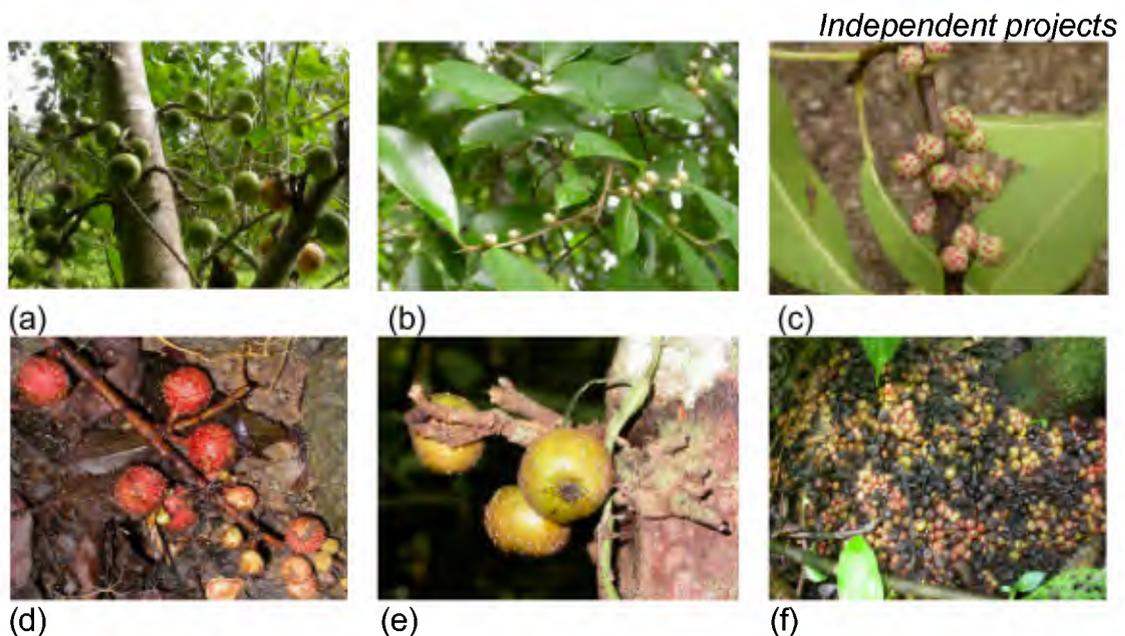


Fig 1 Some fig species at Khao Ban Thad, (a) *Ficus hispida* (b) *F. microcarpa* (c) *F. cocinna* (d) *F. semicordata*, (e) *F. schwarzii* and (f) *F. scortchennai*

Data were compared statistically using linear regression to investigate relationships between the numbers of non-pollinators and inflorescence height in three species, and between foundress numbers and seed production (3 spp.), fruit diameter (5 spp.), and bunch size (6 spp.).

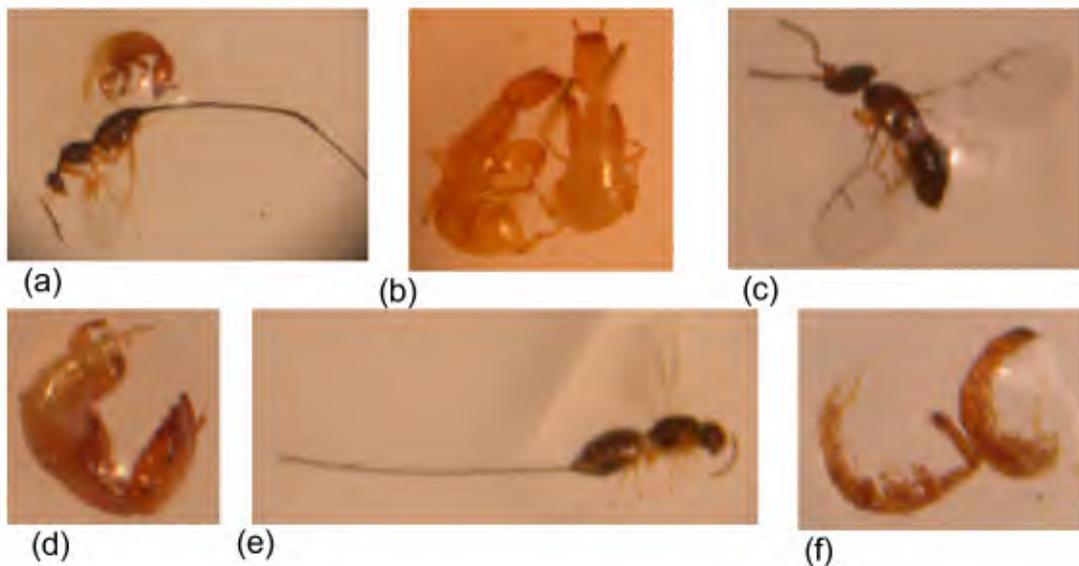


Fig 2 Some fig wasps observed in our study, (a) *Philotrypesis* male (top) and female (bottom), (b) *Ceratosolen* (pollinator) male, (c) *Ceratosolen* (pollinator) female, (d) *Philotrypesis* male, (e) *Platyneura* female, and (f) *Platyneura* male.

## RESULTS

The six species of *Ficus* studied represent a range of fruit sizes, numbers of seeds, numbers of pollinator wasp offspring, numbers of non-pollinator offspring and numbers of foundresses. There is also considerable variation in these variables among fruits within species.

### Independent projects

Linear regression performed to determine correlation between the abundance of non-pollinators with respect to inflorescence position in three species of figs yielded non-significant results. Linear regression analysis of the number of seeds and foundress numbers yielded non-significant results for all the species except for that of *F. schiwarzii* ( $p < 0.05$ ; Table 1). Regression analysis was also performed to determine correlation of the fruit diameter and foundress numbers. Only that of *F. semicordata* showed statistically significant results ( $p < 0.05$ ; Table 2). Regression analysis of the bunch size and foundress numbers yielded significant results only for *F. hispida* ( $p < 0.05$ ; Table 3).

Table 1. Summary of linear regression analyses of seed numbers and foundress numbers in three dioecious *Ficus* species.

Species	Df	R <sup>2</sup>	f-value	p-value
<i>Ficus fistulosa</i>	4	0.004	0.118	0.920
<i>Ficus scortchenii</i>	4	0.038	0.120	0.712
<i>Ficus schiwarzii</i>	14	0.322	6.167	0.027

Table 2. Summary of linear regression analyses of fruit diameter and foundress numbers in five *Ficus* species.

Species	Df	R <sup>2</sup>	f-value	p-value
<i>Ficus fistulosa</i>	11	.0007	0.007	0.945
<i>Ficus schiwarzii</i>	34	0.042	1.443	0.238
<i>Ficus hispida</i>	14	0.078	1.100	0.313
<i>Ficus coccinna</i>	10	0.091	0.903	0.367
<i>Ficus semicordata</i>	11	0.356	5.535	0.040

Table 3. Summary of linear regression analyses of bunch size and foundress numbers in six *Ficus* species.

Species	Df	R <sup>2</sup>	f-value	p-value
<i>Ficus fistulosa</i>	11	0.023	0.241	0.634
<i>Ficus scortchenii</i>	4	0.028	1.154	0.361
<i>Ficus schiwarzii</i>	34	0.002	0.063	0.803
<i>Ficus hispida</i>	14	0.583	18.16	.0009
<i>Ficus coccinna</i>	10	0.057	0.543	0.480
<i>Ficus semicordata</i>	11	0.214	2.730	0.129

## DISCUSSION

There was no significant correlation between the abundance of non-pollinators and inflorescence height in three species of fig. This implies that non-pollinators do not express preferences for fruits of particular heights. This could be because of limits on parasitoid search time imposed by the abundance of ant predators observed among the fruits (Weiblen *et al.* 2001). Or possibly because our conjecture that predation pressure was higher nearer the ground was incorrect. Ants, for example, were observed patrolling up the trunks of several of the trees sampled.

A significant correlation between seed and foundress numbers was observed only in *F. schiwarzii*. This could be because of the availability of a large sample size from which to identify trends, as compared to the other species in the study. Previous studies on monoecious figs indicated that variation in the proportion of flowers that develop to produce pollinator wasps and

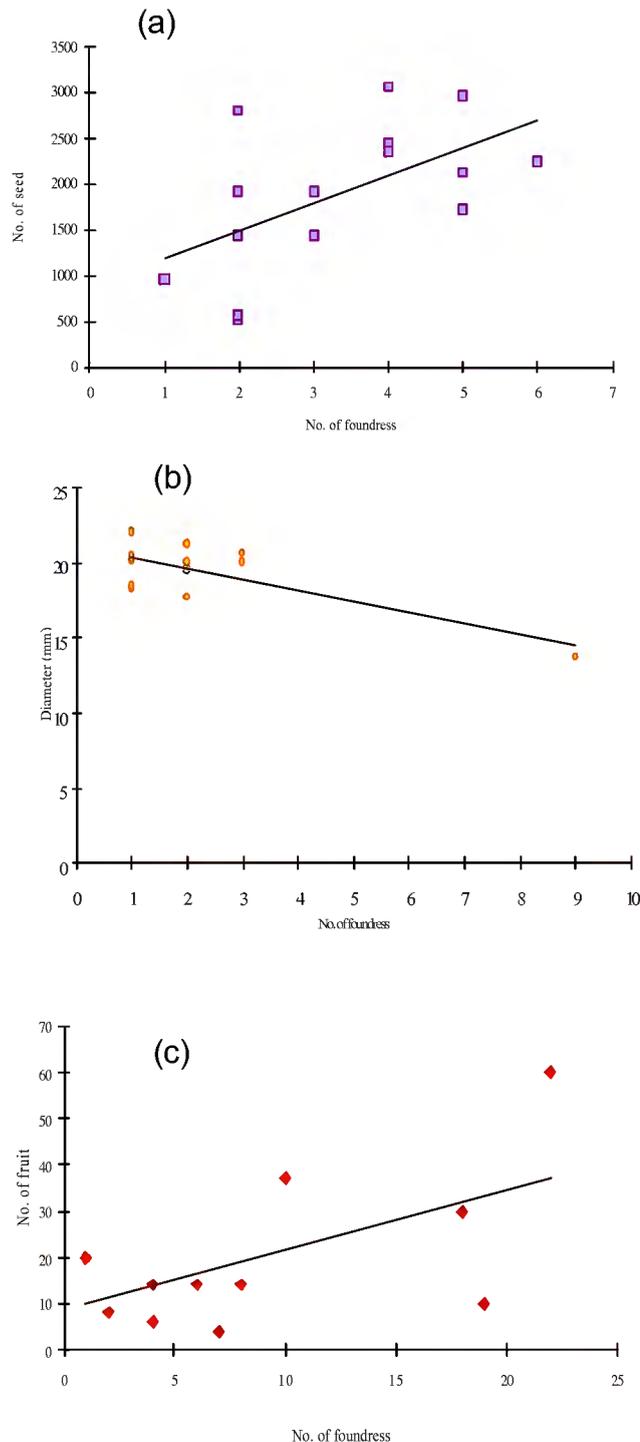


Fig 3 Graphs illustrating the regression analyses that showed statistically significant ( $p < 0.05$ ) results. (a) Relationship between the number of seeds and foundresses in *F. schiwarzii*. (b) Relationship between inflorescence diameter and foundress number in *F. semicordata*. (c) Relationship between number of fruits in a bunch and foundress number in *F. hispida*.

viable seeds represents an interaction between the number of ovules and pollen availability (Herre and West 1997). Flower development was associated with increased numbers of foundresses per fruit, suggesting that flower development within a fruit may be limited by pollen

availability. Inflorescences in which there are more female flowers have been shown to produce more viable seeds and more pollinator wasp offspring. However, an increase in the number of foundresses also resulted in a greater proportion of ovules consumed by pollinator larvae (Herre and West 1997). This is of ecological importance to the continued existence of such highly specialized species as the fig and fig wasps. In dioecious figs, including the three species studied by us, there may be a different dynamic and pollen may not normally be a limiting factor in the production of seeds (Harrison & Yamamura 2003).

The negative correlation observed between the diameter and foundresses for *F. semicordata* is unexpected, as larger fruits were anticipated to be able to contain more foundresses. This may be the result of experimental errors as the higher density of seeds in the larger fruits may have impeded the detection of foundresses. Alternatively, the larger inflorescences may have been pollinated earlier so had more time to develop.

The correlation between the number of fruits and foundresses as observed for *F. hispida* may imply that the presence of a larger bunch of inflorescences is more successful at attracting wasps as compared to smaller bunches. This strategy may be adopted especially in instances where the same species of trees are not found close together.

#### ACKNOWLEDGEMENTS

We would like to express our heartfelt gratitude to Rhett Harrison and Shao-chung Huang for their help throughout the project, without which this would not have been possible.

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## Effects of quality and quantity of food on the foraging area of *Macrotermes carbonarius* in tropical rain forest

Siew Chin Chua & Juei Ling Hsu

### ABSTRACT

*Macrotermes carbonarius* belonging to the family Termitidae, is a common termite found in habitats ranging from lowland rain forest to plantations. Using linear regression we found that dead wood surface area was a significant predictor of the foraging area of a colony. Foraging area decreases with increasing wood surface area. Neither dead wood volume nor amount of leaf litter affected foraging area. We also found that *M. carbonarius* colonies change their foraging area frequently, and this is probably related to the food quantity and quality that is available.

### INTRODUCTION

In lowland tropical rain forest, termites are a major component of the soil macrofauna and contribute to the decomposition process (Whitmore 1998). Termites are a unique feature of tropical and subtropical regions. There are over 2,300 species of termites in the world. They are eusocial insects with three main castes, namely the reproductives, soldiers and workers. They are vital for the release of nutrients locked up in dead plant materials, using protozoan symbionts living in their guts to decompose cellulose. The single higher family Termitidae, which is dominant in many rain forests, differs in having bacterial symbionts.

Macrotermitinae is a subfamily of Termitidae, which cultivates subterranean fungus combs. In this study, we investigated the effect of the quality and quantity of food on the foraging area of *Macrotermes carbonarius* (Hagen). This study can help to ascertain the importance of *M. carbonarius* in nutrient recycling in the tropical rain forest. We were also interested in its foraging behaviour and strategy.

We examined the following hypotheses; (1) *M. carbonarius* require a variety of food, and (2) Their foraging area is determined by the quality and quantity of food available.

### METHODS

#### Study site

The study was conducted in Khao Chong Wildlife Extension and Conservation Center (7°33'N 99°47.4'E), along the trails in the secondary lowland rain forest in the vicinity of the center's buildings. The forest is evergreen lowland rain forest but experiences a three month dry season.

#### Study organism

Our study organism, *M. carbonarius*, is a large termite species and has a free ranging foraging habit (Tho 1992). It is confined to lowlands below 160 meter and is the only open-air foraging species within this subfamily (Sugio 1995). It is common to all low-flat lying land, ranging from lowland dipterocarp forest and coastal forests to plantations and other rural habitation (Tho 1992).

#### Colony size

The colony size was determined using the catch and recapture method. One hundred termites were marked with marker pens. We used the Petersen method to estimate colony size. The function is:  $N = \frac{n_1(n_2+1)}{m_2+1} - 1$

$n_1$  = number marked and released on the first occasion.

$n_2$  = total number caught on the second occasion

$m_2$  = number of marked animals found on the second occasion

#### Quantifying amount of leaves and wood

The colonies were located and specimens of the soldier and worker termites collected for identification. For each colony, the extreme foraging points were first marked with tapes. Foraging area was measured in meters from the nest entrance to these points, using tape measure and compass (Fig 1). Leaf litter in the forage area was quantified by weight in kilograms and by area. Where the foraging area crossed a forest trail, the area of the trail was deducted to get a better estimate of leaf litter cover. Leaf litter in a 20×20 cm quadrat area was weighed at three different spots. The average was used to estimate the total weight of leaf litter in the foraging area. The amount of dead wood in the forage area was quantified by measuring the diameter and length of all dead wood more than 1 cm in diameter.

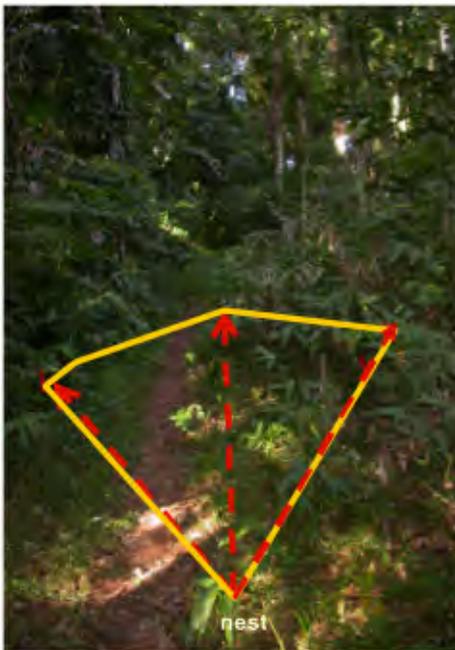


Fig 2 Diagram of method for measuring foraging area of a colony.

In order to compare the relative importance of various food types, the number of termites foraging on a particular food type was measured by counting the number of individuals passing along the access trail in one minute. In an attempt to assess whether the termites show preference for different wood quality, we categorized dead wood into four grades;

- Grade 1: still green,
- Grade 2: brown but no sign of decay,
- Grade 3: some signs of decay,
- Grade 4: rotten wood that crumbles easily.

#### Data analysis

All data analysis was done using S-PLUS. Linear regression was used to test the effect of surface area of wood, weight of leaf litter, leaf cover and volume of wood, on foraging area. We also used linear regression to test the relationship between number of termites, and the surface area of leaves and surface area of wood.

RESULTS

We were only able to calculate the size of two colonies, as these were the only ones that remained at the same foraging site for two days.

Table 1 Summary of colony size

Colony #	No. of individuals
4	84165
5	266251

There was substantial change in the size of foraging area for both colonies from one day to the next (Table 2).

Table 2 Change in foraging area of colonies between days

Colony #	Foraging area on day 1	Foraging area on day 2
4	8.63	5.17
5	2.10	8.62

The results show that only dead wood surface area was a significant predictor of foraging area and that foraging area decreases with increasing dead wood surface area (Fig 2).

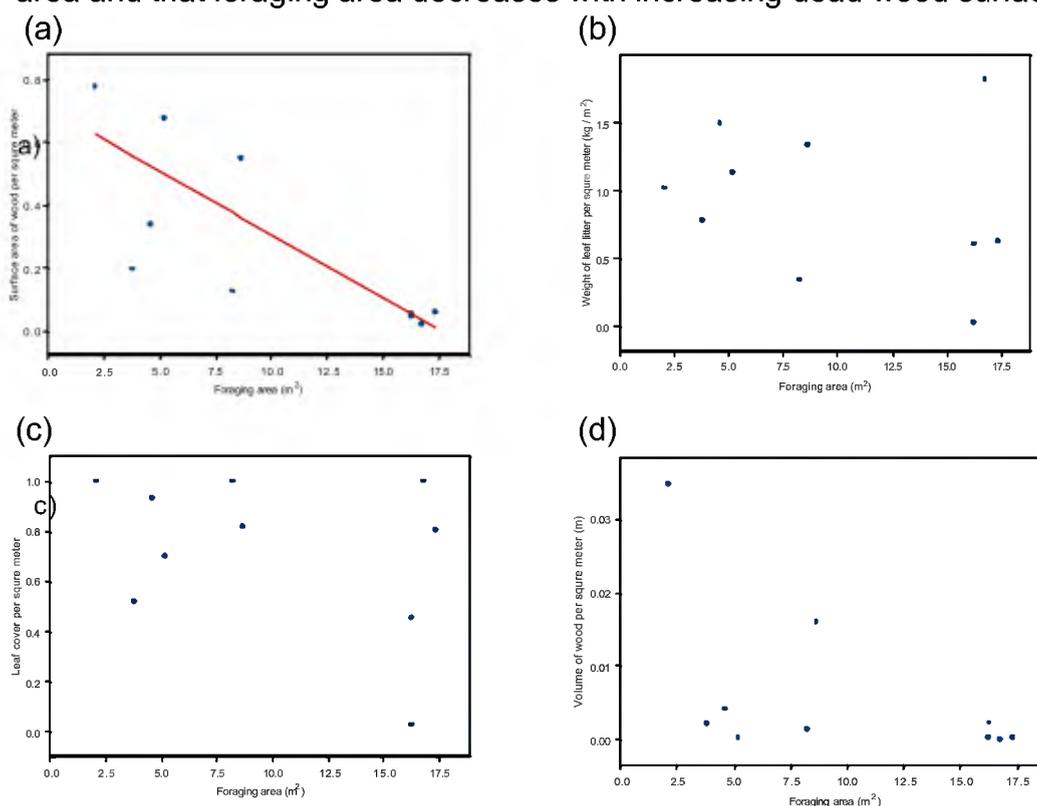


Fig 1 Graphs showing linear regression of (a) foraging area and surface area of wood ( $r^2=0.5836$ ,  $p=0.0101$ ); (b) foraging area and volume of wood ( $r^2=0.2609$ ,  $p=0.1314$ ) (c) foraging area and leaf cover ( $r^2=0.1251$ ,  $p=0.3161$ ); (d) foraging area and weight of leaf litter ( $r^2=0.0579$ ,  $p=0.5031$ ).

Linear regression analysis found no significant correlation between number of termites recorded on an access trail, and the surface area of leaves ( $p = 0.1241$ ) or surface area of wood ( $p = 0.9140$ ).

## DISCUSSION

Our observations took place over three consecutive days. Unlike Sugio (1995), who noted that *M. carbonarius* only forage in the dry season and at night, we observed them active on sunny days in the wet season as well as at night. Sugio (1995) also observed that *M. carbonarius* changed their foraging area irregularly and that in most instances, a single foraging site and one foraging hole was used for each foraging bout. We observed similar foraging behaviour, except that up to three nest entrances were used. We were able to measure the foraging area of two colonies for two consecutive days and the results indicate that foraging area could change substantially from one day to the next. We speculate that in areas with richer food resources, such as the large pieces of dead wood, the termites would utilize the same foraging area for longer periods. At one colony, we encountered a mud-constructed “pavement” as mentioned by Sugio (1995) (Fig 3). This trackway cut through a dirt track of about 3m. It was abandoned after one day. In view of the energy expended in constructing this trackway, which lead solely to some dead leaves on a branch, it suggests the importance of certain food to *M. carbonarius*.



Fig 3 Photograph of “pavement” constructed by *Macrotermes carbonarius*.

We observed *M. carbonarius* eating small fallen fruits, leaves and wood of varying decomposition stages. Since *Macrotermes* spp. farm fungus, the latter may explain why leaves of different decomposition levels, some of which still rather fresh, were collected by the worker termites.

Linear regression analysis indicated that the number of termites on a trail to a particular food source was not significantly correlated to the surface area of leaves or to of dead wood, implying that the termites show no preference for the size of a particular food resource. However, it was difficult to count the number of termites utilizing a particular food resource, as the trails tended to converge and diverge, and the termites also often foraged elsewhere along the trails. This problem prevented us from assessing the termites' preference for dead wood of different quality.

Our results showed that wood surface area was the only significant predictor of foraging area. Increased dead wood surface area decreased the size of foraging area. Weight of leaf litter, surface area of leaf and volume of wood had no effect on size of foraging area.

We suggest that leaves are a cheap resource readily found everywhere, hence have no effect on foraging area. Wood, on the other hand, is an important resource for termites, as it provides a substantial amount of food, and is more patchily distributed.

Wood volume showed no significant relationship with foraging area, which could be because termites often do not utilize the entire volume of a piece of dead wood, depending perhaps on the level of decomposition of the wood. Hence wood surface area is a better estimate of the true amount of dead wood resource available to the termites. Takamura (2001) mentioned that termites have differential selection for soft and hardwood, as the latter have chemical compounds that deter termites. Wood density could, therefore, be another factor affecting forage selection in termites. In our study, we were unable to factor this into the assessment.

## CONCLUSION

Our study supports the hypotheses that *M. carbonarius* requires a variety of food. This ranges from fairly fresh dead materials to rotten wood. Our results show that wood surface area is a significant predictor of foraging area, and that with increasing wood surface area, the foraging area decreases.

## ACKNOWLEDGEMENTS

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## Species diversity of insects in three different habitats along a stream

Thanakorn Lattirasuvan and Sawat Sanitjan

### ABSTRACT

The species diversity of insect in three different habitats (natural forest, *Azadirachta* plantation and *Eucalyptus* plantation) along the stream at Khao Chong was investigated on 8th to 10th July 2005. Overall there were 82 species from 12 orders. The natural forest had 48 species in 10 orders, *Azadirachta* plantation had 32 species in 8 orders, and *Eucalyptus* plantation had 41 species in 10 orders. The Shannon diversity index was highest in the natural forest (3.36), following by *Eucalyptus* plantation (2.66) and *Azadirachta* plantation (1.63). The similarity was low between all habitats. The majority of individuals were collected during the day, and the most important insect orders were Hymenoptera (Formicidae), Diptera and Coleoptera. Most insects were found near the stream bank.

### INTRODUCTION

There are an estimated 30 million species of insects in the world. Only about one million of them have been named (Castner 2004). There are insects everywhere in the world and different species are found in different habitats.

Nowadays there are high levels of deforestation through human activities and species compositions in natural forest are changing and unstable, as the forested area is divided into small fragments. If forests are disturbed, species that cannot live in the disturbed areas will decrease, but other species that can live in the disturbed forest will increase. So the species composition of insects in the forest depends on the conditions.

In this study we compare the species diversity of insect in three different habitats, natural forest, *Azadirachta* plantation, and *Eucalyptus* plantation. We expect different habitats will have different abundances of some species and in some cases different species. It is possible some species could be used as indicators of the quality of habitat.

### MATERIALS AND METHODS

#### Study site

This study was conducted at Khao Chong Wildlife Extension and Conservation Center, Trang, Thailand. We compared three habitats (natural forest, *Azadirachta* plantation and *Eucalyptus* plantation). The *Azadirachta* plantation and *Eucalyptus* plantation were located near the center buildings, but the natural forest was located at the Ton Piew waterfall, about 2 km upstream. All sample sites were located along a stream bank.

#### Methods

Insects were collected from 8th to 10th July 2005. In each habitat pitfall traps, a malaise trap, net swipe sampling, a stream net and leaf litter sampling were employed. The Malaise trap was erected 20 m from the stream and insects collected twice per day at 08.00 a.m. and 06.00 p.m. Three pitfall traps were placed at three points (0 m, 10 m and 20 m) along a 20 m transect line and collected at the same time as the Malaise traps. Swipe net samples were collected from a 3 m wide area, by sweeping approximately 100 times along the same transect lines as the pitfall traps were located. To collect insects that live at the leaf litter, three litter samples were collected along the same transect lines adjacent to the pitfall traps. Stream-bed insects were collected by kick sampling ten times in a transect across the stream (Kanjavanit 2002). Insects were identified to Family and morpho-species. We calculated the Shannon diversity indices and covariant of similarity indices.

RESULTS

Overall 82 species from 12 orders were recorded. The natural forest had 48 species in 10 orders, the *Azadirachta* plantation had 32 species in 8 orders, and the *Eucalyptus* plantation had 41 species in 10 orders.

The Shannon diversity index was highest for the natural forest (3.36), followed by *Eucalyptus* plantation (2.66) and *Azadirachta* plantation (1.63) (Table 1).

Table 1 Species richness, Shannon diversity index, and individual abundance in three habitats

	Natural forest	<i>Azadirachta</i> plantation	<i>Eucalyptus</i> plantation
Species richness	48	32	41
Shannon diversity index	3.36	1.63	2.66
Individual abundance	182	355	239

The similarity index indicated that the similarity was low between each of the habitats (Table 2).

Table 2 Covariance similarity of the insect faunas sampled in three habitats

	Natural forest	<i>Azadirachta</i> plantation	<i>Eucalyptus</i> plantation
Natural forest		0.43	0.43
<i>Azadirachta</i> plantation			0.30
<i>Eucalyptus</i> plantation			

Some species of insect were only found in one habitat but others were found in two or all three. Nineteen species were found only in the natural forest, 11 in the *Azadirachta* plantation, and 18 in the *Eucalyptus* plantation. In contrast, 7 species from 2 orders were found in all three habitats (Fig 1)

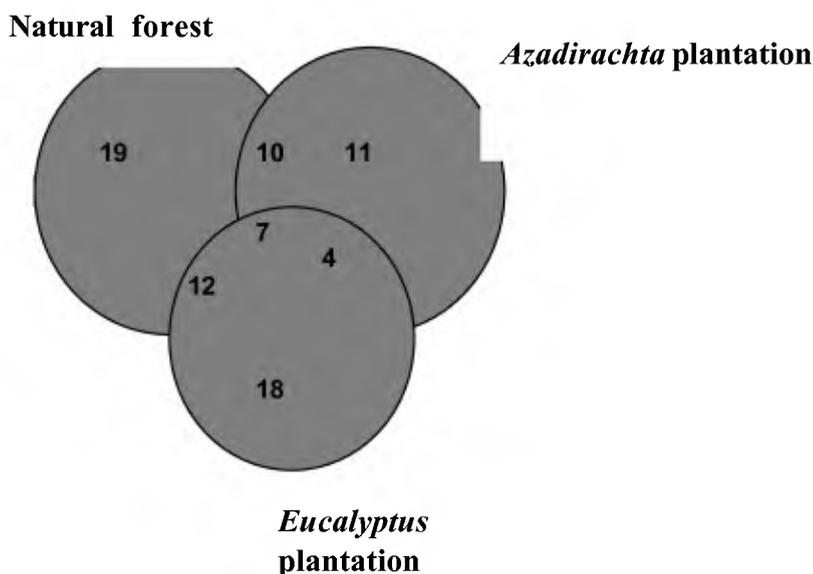


Fig 1 Distribution of insect species among three habitats

Table 3 The number of species and individuals of insect sampled at different distances from the stream

Habitats	0 m		10 m		20 m	
	species	individuals	species	individuals	species	individuals
Natural forest	10 (30.30%)	38 (38.78%)	13 (39.39%)	25 (25.51%)	10 (30.30%)	35 (35.71%)
<i>Azadirachta</i> plantation	4 (33.33%)	201 (78.21%)	5 (41.67%)	29 (11.28%)	3 (25%)	27 (10.51%)
<i>Eucalyptus</i> plantation	4 (30.77%)	23 (34.33%)	4 (30.77%)	27 (40.30%)	5 (38.46%)	17 (25.37%)

A greater number of individuals were caught near the stream but the number of species caught was evenly distributed among sites (Table 3).

Different numbers of species and individuals were collected during the day and at night (Table 4)

Table 4 The number of species and individuals of insects collected during the day and at night

Habitats	Day time		Night time	
	species	individual	species	individual
Natural forest	30	104	18	29
<i>Azadirachta</i> plantation	17	279	18	58
<i>Eucalyptus</i> plantation	21	115	23	111

## DISCUSSION

The species diversity of insects in the three different habitats was different. The natural forest had the highest diversity index (3.36), follow by the *Eucalyptus* plantation (2.66) and *Azadirachta* plantation (1.63). This is unsurprising as the natural forest has a more diverse plant community than either the *Azadirachta* plantation or the *Eucalyptus* plantation. The higher diversity in the *Eucalyptus* plantation may be linked to a more diverse ground flora, although we did not measure this. The natural forest had a richer insect community but the individual abundances were low.

The similarity of the three habitats was low. This was unsurprising given the large differences in habitat types.

More insects were collected during the day than at night. This was especially true for Hymenoptera (Formicidae), Diptera and Coleoptera. Most Hymenoptera are known to be diurnal or crepuscular.

## CONCLUSIONS

The species diversity of insects in three different habitats (natural forest, *Azadirachta* plantation and *Eucalyptus* plantation) along the stream at Khao Chong was different. It was found that the natural forest had the highest diversity (shannon index) follow by *Eucalyptus* plantation and *Azadirachta* plantation. The similarity between habitats was low.

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## Feeding behavior and prey size selection of a glow worm (*Lamprigera* sp)

Ronnie Bibi & Lumyai Ittichan

### ABSTRACT

Two laboratory experiments were carried out to study whether there is relationship between glow worm size and the prey size selection. A total of ten glow worms (*Lamprigera* sp.) and various sizes of snails were used in this experiment. The results showed that glow worm size had no effect on prey size selection, in either choice chamber experiments or T-tube experiments.

### INTRODUCTION

Glow-worms belong to a family of beetles known as the Lampyridae. The glow worm earns its name from its ability to emit a flashing light from its tail. This light has role as a signal to attract a mate in adults and also functioned as a warning indicator to nocturnal predators in larvae. Like many insects, the glow-worm's life is divided into four distinct stages: the egg, larvae, pupae and the adult. The larvae are similar in appearance to the adult female glow worm, but the adult male looks like a normal beetle and can fly. Larvae can be up to 25 mm long, while the female can be up to 18 mm and male up to 12 mm long. Glow worm larvae are active at night and can easily be found in slightly wet areas and with sparse vegetation. They live under stones, inside decomposing logs, under bark and in similar sheltered places. Glow worms move actively searching for their prey, mostly snails and slugs, at night.

This study was carried out to determine glow worm feeding behavior and whether body size affects prey size selection.

### MATERIALS AND METHODS

#### Specimens

A total of ten *Lamprigera* individuals and various sizes of river snails were used in this experiment. Most of the glow worms were obtained from a night survey along the Khao Chong river. Meanwhile the river snails were collected from another nearby stream in nursery area in Khao Chong Peninsular Botanic Gardens.

#### Data Collection

Observations on the feeding behavior of glow worms were made and described in detail. Two laboratory experiments were carried out to see whether the glow worms select prey according to size of the snail. T-tube and container prey choice experiments were conducted. In the T-tube experiment snails of two sizes (small and large) were placed at the each end of the tube (Fig 1). Glow worms were released and allowed to crawl toward into the tube and select the snail in the left or right branches. The container experiment involved putting five difference sizes of snails together in one container into which the glow worm was released and allowed to select a snail (Fig 2).

#### Data Analysis

We used Spearman correlation analysis to test the relationship between glow worm size and prey sized selected.

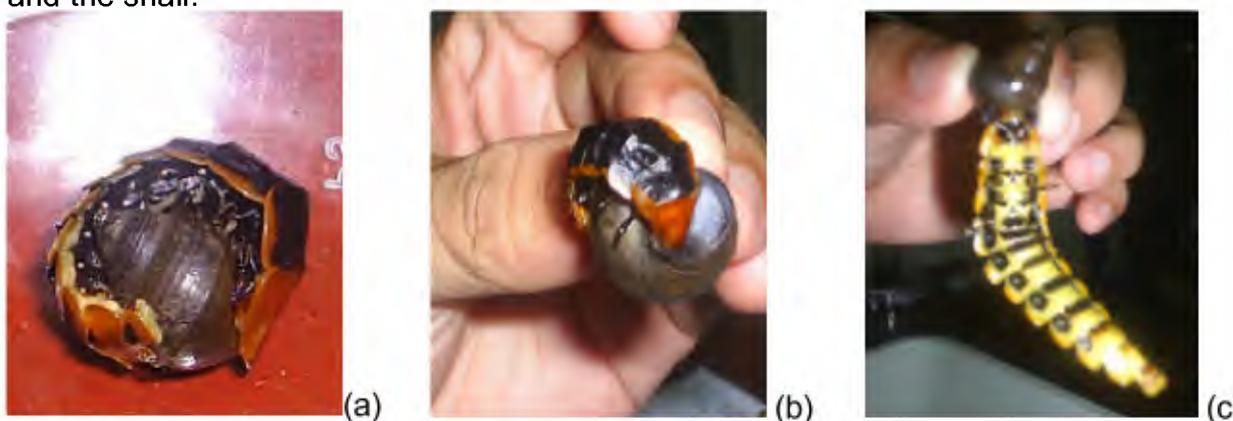


(a) (b)  
 Fig 1 (a) T-tube experiment with two snails placed at both ends of the tube, (b) container experiment with five snails placed together in one petri dish

## RESULTS

### Feeding Behavior

We observed that Glow worms find their prey by using their eyes and by following the snail mucus trail (Tyler 2002). When a Glow worm encountered a snail, it used its sharp and sickle-shaped mandibles to nip the prey. Apparently the glow worm injects toxic fluid through its mandibles to paralyze the snail. The poison is produced in the glow worm's intestine and is able to digest proteins (Tyler 2002). The glow worm then clambered on to the snail shell and began to lap up the digested snail. It extended its head around the lip of the shell when it fed. Glow worms use a sieve of hairs inside their mouth to strain off any lumps of flesh which too large to swallow, and a pair of pointed blades on the inside edges of its mandibles to break pieces into a more manageable size (Tyler 2002). We were able to confirm this through our observations. How long the glow worm took to finish feeding depended on the relative size of the glow worm and the snail.



(a) (b) (c)  
 Fig 2 a) Glow worm eating a snail (side view), b) glow worm eating a snail (top view), c) Biting strength of a glow worm.

Spearman correlation analysis found no significant relationship between the size of glow worm and the size of snail that they selected. The results were equivalent in both experiments (Tables 1 & 2).

## DISCUSSION

Snails and slugs are the preferred prey for glow worms. Upon biting its prey, the glow worm pumps a small amount of toxic into the snail body through the mandibles, which paralyzes the

snail. The feeding process begins shortly after this as the glow worm laps up the partially digested contents of the snail.

Table 1 Spearman correlation analysis of a container choice experiment of glow worm size against prey size selected.

Size of glow worm	Spearman's r	P
Head width	0.192	0.236
Body length	0.163	0.315
Prothorax length	0.092	0.573

Table 2 Spearman correlation analysis result of a T-tube experiment of glow worm size against prey size selected.

Size of glow worm	Spearman's r	P
Head width	0.009	0.954
Body length	-0.028	0.864
Prothorax length	0.140	0.390

We did not find any relationship between the size of the glow worm and the size of the snails selected. Glow worms did not show any tendency to select a particular size of snail, instead they tended to feed the first snail that they encountered. This was shown in the T-tube experiment where once the glow worm had moved toward one side of the tube they never turned back in other direction. Glow worms have an extensible neck which permits them to eat prey much smaller (or bigger) than themselves.

We identified two weaknesses in the experimental design that might have slightly affected our results. Our sample size was not adequate since, both glow worms and snails are represented by a large size range, but finding samples was a problem. We also did not repeat the experiments in the dark or at night, which is the normal feeding habit of glow worms.

## CONCLUSIONS

There was no evidence that glow worms select prey according to size. Thus our initial hypothesis was not supported.

## ACKNOWLEDGMENTS

The authors would like to thank to Rhett D. Harrison, David Lohman, Luan Keng Wang, Shawn Lum and Dr. Chuweewan for the guidance and comments in the completion of this project.

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## Feeding preferences of nectarivorous ants (*Pheidole* sp and *Dolichoderus* sp) for different sugars

Mohammad Hasmawi Bin Ajamain

### ABSTRACT

Ants (Hymenoptera: Formicidae) consume a broad spectrum of liquid sources including nectar and honey dew, which play an important role in their diet, especially in tropical forest. This study compares the feeding preferences of *Pheidole* sp. and *Dolichoderus* sp. for different sugars. Five colonies from each species were tested. This study found that the ants showed a significant preference for particular sugars, but there was no significant difference in the preferences between species.

### INTRODUCTION

Hymenopterans, the “the membrane winged” insects, include bees, ants and a large number of taxa collectively referred to as wasps (Donat et al. 2000). The Hymenoptera include famous examples of social insects, such as honeybees and true ants; these insects have developed a social system in which members are divided into worker, drone and queen castes. Ants, the family Formicidae, come in a variety of sizes ranging from as small as 0.8 mm to 4 cm in length. They have the distinguishing characteristics of a narrow pedicel composed of one or two joints between the thorax and abdomen. They also have characteristic elbowed antennae. Their food requirement and choice vary among species and conditions. Some ants favor “sweets”. Others are meat eaters and others feed on seed. Nectar and other plants products play an important role in the diet of many ant species, especially those of the adults (Donat et al. 2000). In multi-species communities, resource selection is affected by different food preferences and conditional effects such as competition for food and colony requirements. These processes maybe crucial in niche partitioning of species-rich nectarivore ant assemblages. In one study preferences among carbohydrates were similar among ant species (Nico and Konrad 2004), but most of these preferences were found under experimentally controlled conditions. The natural environment can be much more complex and preferences observed in the laboratory might not translate into actual resource visitation in the field (Nico et al. 2004). This study compares the feeding preferences for different sugars of two co-existing ant species (*Pheidole* sp and *Dolichoderus* sp) , in their natural environment.

### MATERIALS AND METHODS

This study was implemented near the buildings of the Khao Chong Wildlife Extension and Conservation Center. For both species of ants (*Pheidole* sp. and *Dolichoderus* sp.) five colonies were located. This study used six different types of concentrated sugar (glucose, fructose, sucrose, maltose, raffinose and melizitose). Capillary tubes filled with the different sugars were placed on a pole near the ants' nests. After being left for 2 hours, the difference between the initial and final volume of sugar was measured. Evaporation was estimated from a capillary tube of water. These measurements were done twice per day and were collected for two consecutive days.

### Data analysis

Nested analysis of variance was used to examine the feeding preferences for different sugars and the differences between species in feeding preference. The volume of sugar consumed was converted to a proportion of the total sugar consumed in each replication, and arcsin transformed. Multiple observations were nested within colony.

## RESULTS

Fig 1 shows the average volumes of sugar taken. *Pheidole* sp. took a greater volume of all sugars, excluding melizitose and raffinose.

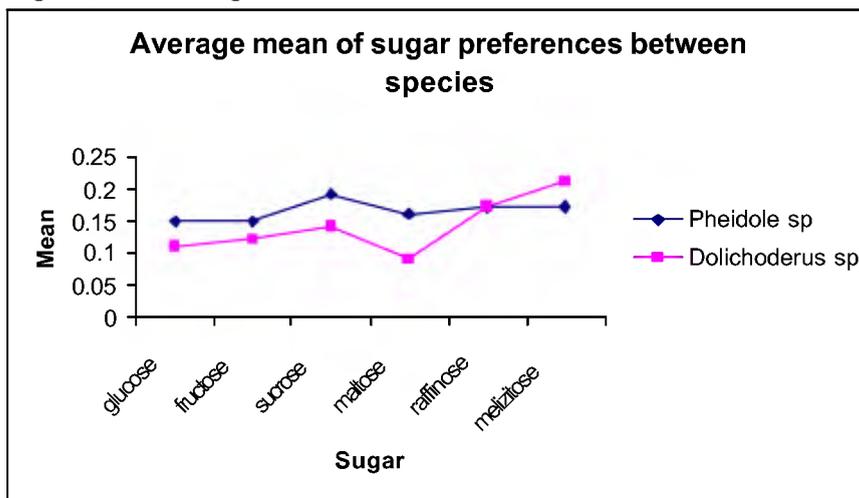


Fig 1 Mean proportion of different sugars consumed in two ant species

Overall there was a highly significant difference across species, colonies, and sugars (Table 1) but in the separate effects tests the only significant effect was the type of sugar (Table 2). Thus, ants showed significant preferences for particular sugars, but there were no significant differences in preferences among colonies or between species.

Table 1 Nested analysis of variance table

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	59	1.2725135	0.021568	1.6908
Error	162	2.0665500	0.012756	Prob > F
C. Total	221	3.3390635		0.0052

Table 2 Effect tests for the nested ANOVA (Table 1)

Source	DF	Sum of Squares	F Ratio	Prob > F
species	1	0.0012321	0.0966	0.7564
colony	4	0.0004527	0.0089	0.9998
sugar[species,colony]	50	1.2710250	1.9928	0.0007
species*colony	4	0.0006437	0.0126	0.9997

## DISCUSSION

There was a significant preference ( $p < 0.001$ ) for different sugars but no significant differences in preference among colonies or between species. Therefore, our initial postulate that ants prefer certain sugars was supported. However, our hypothesis that species partition their carbohydrate resource was rejected, as no differences in feeding preferences for sugar between species were found. This confirms the results of the earlier laboratory experiments (Nico et al. 2004) in a field setting.

## CONCLUSIONS

There were no differences in feeding preferences between the two nectarivorous ant species (*Pheidole* sp. and *Dolichoderus* sp.).

#### ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Dr. Rhett Harison, Dr. David Lohman and Ms. Luan Kheng for their encouragement. My appreciation also goes to Dr. Sarayudh Bunyavejchewin for hosting the course. I wish to give my sincere thanks to my colleagues for their care and support throughout the making of this study.

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## The effects of fruit patch size on visitation by understory birds

*Bharath Sundaram*

### ABSTRACT

This study examines the effect of fruit patch size on visitation by understory birds in a dipterocarp forest in Khao Chong, Thailand. I used artificial fruits made from modelling clay to simulate two different patch sizes of fruit. I made direct observations of bird visitation and also tallied the number of peck marks at the end of the 72 h study period. There were no significant differences between visitation rates across the two fruit patch sizes, possibly due to an insufficient number of observations. However, larger patches had significantly higher peck rates than smaller patches.

### INTRODUCTION

A large proportion of vascular plants in tropical rain forests are dispersed by birds or mammals (Corlett 1998). Interactions between the plant and the frugivore are often mutually beneficial: the plant benefits by increasing the chances of directed dispersal of its seeds, and the frugivore benefits by gaining a food source. A total of 17 families of birds (15.6 %) are strictly frugivorous, but 23 families have a mixed diet of fruit and animal prey (Jordano 2000). Among bird families in Southeast Asia, the Bucerotidae (hornbills), Megalaimidae (barbets), Columbidae (fruit pigeons), Pycnonotidae (bulbuls), and Nectariniidae (flowerpeckers) are considered the most important frugivores and seed dispersers (Corlett 2002).

The patchiness of fruit resources can affect the foraging behaviour of understory birds (Levey 1988). From the view of optimisation, a bird benefits from using clumped fruit resources as it minimises search time, and maximises time spent processing food items. From the plant point-of-view, the production of fruits in clumps may also be advantageous by satiating seed predators.

The objective of this study is to examine the effects of fruit patch size on visitation by understory birds in a dipterocarp forest in Khao Chong, peninsular Thailand.



Fig 1 Experimental set up (a) fruit patch containing 10 artificial fruits, and (b) a patch with 100 artificial fruits

### MATERIALS AND METHODS

#### Study area

The study sites were located on a trail adjoining the 24 ha forest dynamics plot in a lowland dipterocarp forest at Khao Chong, Thailand. The overstorey of this forest is dominated by

dipterocarps, *Dipterocarpus* and *Shorea*, and the understorey is dominated by members of the Rubiaceae, Annonaceae, and Malvaceae. The average height of the forest is 25-30m.

#### Experimental design

Many workers have used artificial fruits to investigate edge effects, colour preference, and understorey bird assemblages (Galetti et al. 2003, Alves-Costa and Lopes 2001). I used artificial fruits made from modelling clay to simulate patches of two different sizes. All fruits were red in colour. Fruits were spherical and approximately equal size (10 mm to 12 mm). The fruits were attached to understorey plants of comparable size and leaf arrangement. The eight sites were approximately 50 m apart, arrayed along a trail with alternate small patches (10 fruit) and large patches (100) fruit (Fig 1).

#### Data collection

Fruits remained in the field for a period of 72 hours. I collected bird visitation data by observing bird activity at each site for a period of 1.5 h spread over three days. I counted peck marks on all fruits at the end of the 72 hour period.

### RESULTS

#### Bird visitation

I observed a total of 7 species of birds visiting and pecking the fruits. There was no significant difference in the bird visitation rates between the two patch sizes (Kruskal-Wallis chi-square = 1.4737, df = 1,  $p = 0.2248$ ).

#### Peck-rates

The number of peck marks was tallied for each site at the end of the 72 h sampling period and the peck rate (# pecks / patch size) calculated. There was a significantly higher rate of pecks in the larger patches (Kruskal-Wallis chi-square = 5.3976, df = 1,  $p < 0.05$ ).

### DISCUSSION

This study documents the effects of fruit patch size on visitation by understorey birds. Results from fruit peck rates strongly indicate that birds do tend to find and use larger fruit patches more than smaller fruit patches. A few reasons may explain the results. Understorey birds, probably home into larger patches because larger patches give out a bigger signal than smaller patches and are therefore easier to find, and that finding and feeding on larger fruit patches is an optimal way to forage.

Bird visitation data, however, was not significantly different across fruit patch sizes. A period of 1.5 hours per site was evidently not enough to capture a sufficient sample of bird visitation. One can expect the bird visitation data to start looking like the peck rate data with many more hours of observation at each site. Larger sample sizes will also shed more light on whether there is a difference in the types of birds that use small and large patches. The results suggest there is selection pressure on plants to produce fruit in larger crops. The fact that many plants still produce small crops requires further examination.

### ACKNOWLEDGEMENTS

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## **Distribution of amphibian diversity among different habitats in a wet evergreen forest**

*Dayantha Withanage*

### **ABSTRACT**

Frogs and toads were sampled from different habitats at Khao Chong, Thailand using visual encounter transects.

### **INTRODUCTION**

Amphibian diversity is a good indicator of the condition of a particular environment as it is sensitive to a number of environmental characteristics. Species composition and species richness of tropical and temperate zone amphibian communities change over gradients in precipitation, soil moisture, altitude, forest type, and forest structure. Although the mechanisms for these responses are unclear, amphibians' moist, permeable skin, terrestrial and semi-terrestrial reproduction, and the susceptibility of amphibian eggs to desiccation suggest physiological limitations. Co-variation between insect composition and abundance with numerous forest characteristics suggests that prey base may be an influence as well.

Traditionally, the living Amphibians have been grouped into three classes (Anura – frogs and toads; Urodela- newts, salamanders, mudpuppies etc; Gymnophiona- caecilians). Class Anura consists of 22 families, but Family Bufonidae (300 spp.) and Ranidae (400 spp.) are considered the true toads and frogs, respectively.

Normally frogs have bulging eyes, strong long webbed hind feet that adapted for leaping and swimming, smooth or slimy skin (generally frogs tend to like moister environments), and they tend to lay eggs in clusters. Toads have warty, dry skin (usually preferring dryer climates), parotid glands behind the eyes, stubby bodies with short hind legs (for walking instead of hopping), and they tend to lay eggs in long chains.

### **MATERIALS AND METHODS**

#### **Study site**

In order to find out whether there is a distinct variation in frogs and toad diversity among different habitats, near a stream and inside the forest, amphibians were sampled along the Khao Chong river. Khao Chong is located 80-700 msl, with an annual rainfall of 2700 mm and mean temperature of 27°C. It experiences two seasons – the rainy season from May to January and the dry season from February to April. The vegetation of this park is tropical wet evergreen forest.

#### **Amphibian Sampling**

The survey was carried out by laying ten parallel 75m transects. Each transect ran from the stream edge into the forest and thus all transects represented near stream habitats and forest habitats. The same worker conducted all visual encounter sampling using a 4.5 V headlamp, starting at 19.00 and searching at a rate of 1.25 m min<sup>-1</sup>. All amphibians within 2 m of the transect line were captured and identified. When identification was problematic, amphibians were placed in bags for later identification. For amphibian identification, "A Photographic Guide to Amphibians in Thailand" Tanya (2003) and "Amphibians and Reptiles in Thailand" Nabhitabhata (2000) were used.

To compare the diversity of frogs and toads near stream and in the forest, Shannons Diversity Index was used. The sample size proved insufficient for more details statistical analysis.

RESULTS

Table 1 shows the total of amphibian individuals collected from each habitat. A total of 84 specimens were collected from three different habitats, comprising frogs 76.19%, toads 13.10%, others 10.01%.

The total number of individuals collected was the highest for near streams (60) followed by along road (15) and inside the forest (9). Fifty-six frogs were recorded from the stream and eight from near a road (Fig 1). A total of eight toads were recorded from the forest and two individuals were sampled from near the stream.

Highest frog diversity was recorded from the stream and adjoining land area (Shannons index 1.47), but none were recorded within the forest. Toad species diversity within the forest was relatively high (1.06) (Fig 1), but one toad species (*Bufo asper*) was also recorded near the stream.

Table 1 Total no of amphibians recorded from each habitat.

Species	Stream	Road	Forest
<b>Frogs (Ranidae)</b>			
<i>Limnonectes kuhlii</i>	8		
<i>Rana erythraea</i>	11		
<i>R. nigrovittata</i>	22		
<i>R. livida</i>	4		
<i>Occidozyga martensii</i>		8	
<i>Hoplobatrachus rugulosus</i>	11		
<b>Toads (Bufonidae)</b>			
<i>Bufo macrotis</i>			4
<i>B. parvus</i>			2
<i>B. melanostictus</i>			3
<i>B. asper</i>	2		
<b>Others</b>			
<i>Polypedates leucomystax</i>	2		
<i>Microhyla heymonsi</i>		7	

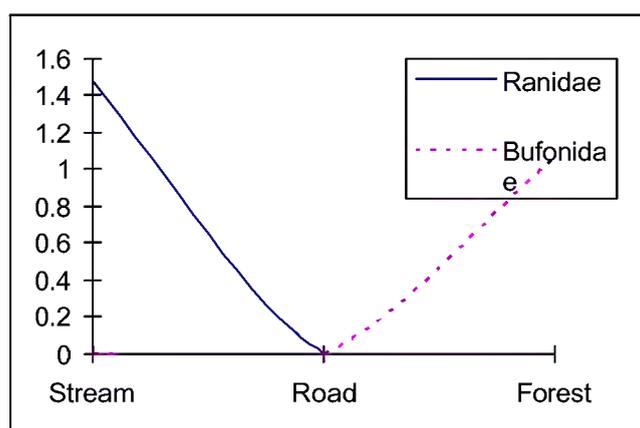


Fig 1 Shannon's diversity index for amphibians in near stream and forest habitats

## DISCUSSION

Most frogs were found near the stream, while most toads were found in the forest, as one would predict from their life-histories. Frogs have a moist skin and therefore require wetter habitat than toads, which have a drier, warty skin. However, insufficient sample sizes prevented statistical verification of this pattern and therefore one cannot reject the null hypothesis that the distributions were random.

Two individuals of Rhacophorid (*Polypedates leucomystax*) were also recorded near the stream. As normally they are tree dwelling frogs most probably these two individuals had been here to lay eggs.

## ACKNOWLEDGEMENT

I would like to express my sincere gratitude to Dr. Rhett Harison, and Ms. Luan for their encouragement and help given to me to make this project a success. My sincere thanks go to Dr. Sarayudh for facilitating us. I wish to give my sincere thanks to my colleagues for there moral support.

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## Microhabitat selection by gliding lizards (genus *Draco*)

Shao-chang Huang & Jing-Xin Liu

### ABSTRACT

Gliding lizards are an obvious target for predators while they perch on smooth tree trunks. Lizard body color contrast with the tree bark color, as well as availability of food resources, may be very important for determining microhabitat selection in gliding lizards. We investigated gliding lizard microhabitat selection, and found that they preferred smooth tree trunks without epiphytes. The fragmented coloration pattern on the lizard matched with the background bark of tree, possibly making it difficult for predators to detect lizard. The same ant species was observed on tree trunks with lizards and surrounding trees, which may be a possible food resource for the lizards. Therefore, the lizards' microhabitat preferences were apparently based on predator evasion, because food was evenly distributed.

### INTRODUCTION

Gliding lizards (Genus *Draco*) belong to the family Agamidae. There are 11 species in the genus *Draco* in Thailand. The most obvious character for the genus *Draco* is the possession of extensive wings, which they use to glide to the other trees. Gliding lizards are arboreal spending most of their time on the trunk (Cox et al. 1998). Stationary lizards on the trunk present easy targets for predators. Hence, to avoid predators, the match between the lizard body color and tree trunk color may be important. Apart from predator avoidance, foraging behavior may also be a factor affecting the choice of microhabitat. The main prey of gliding lizards are ants, insects and some other invertebrates (Cox et al. 1998).

Our objectives for this study were to investigate if 1) gliding lizards express a microhabitat preference, and 2) if there is a correlation between the characteristics of surrounding trees and the choice of microhabitat.

### MATERIALS AND METHODS

The study was carried out at Khao Chong, Trang province, Peninsular Thailand. We selected three habitats to conduct this study. First was the primary forest behind the canteen. The understorey vegetation was complex and there was high and closed canopy. Second was the forest in front of the buildings, which was planted, the understorey plantation was simple, and the canopy was low and closed. The third was a planted forest on the far side of the river, populated by a single species. The forest had a high canopy and the forest floor was covered with grass.

This study was conducted from 8th to 10th July. Hairston (1957) demonstrated that the active time of genus *Draco* was from 8:00 am to 11:00 am and from 13:00 until evening. Hence, we focused on this period. A transect survey was conducted in these three habitats. Walking speed was 100 meters per hour to search for trees with gliding lizards. We recorded the position of the lizard, tree height from ground to the point of branching, the diameter at breast height (dbh) and the presence of extra-bark substrate. The ratio of lizard height to tree height was calculated and the dbh was categorized into six ranges: 1) <10 cm, 2) 10-20 cm, 3) 20-30 cm, 4) 30-40 cm, 5) 40-50 cm and 6) >50 cm. The coloration of the lizards and the bark was classified by a single person into five categories according the color intensity. Hairston (1957) showed that gliding lizards could glide for about 8 m to 9 m. Therefore, we recorded the trees surrounding a lizard to 9 m.

Date analysis was done in SPSS version 11.5. For the data from lizards and trees with lizards, we ran one-Sample Kolmogorov-Smirnov Test to explore the normality of date when

needed. Based on the normality of the data, correlation tests were done between lizard height and tree height, as well as between the distance from canopy to the lizard and lizard height. We ran Chi-Square tests for the ranks of color similarity between lizard and the tree that they occupied, external substrate, dbh of the trees occupied by lizard and the roughness of the trees to test whether the gliding lizards we surveyed were selective with respect to these factors.

## RESULTS

In these three habitats, 33 lizards were found in 27 trees, five in primary forest, 12 in the forest front of the classroom and 16 in the forest on the far side of river. Twenty four of 27 trees were without epiphytes, and three of them had a few epiphytes (Fig 1). The average height of stationary lizard was  $3.05 \pm 0.32$  meters. The ratio of the lizard height to tree height was  $0.29 \pm 0.03$ . There was no significant association between gliding lizard body color and tree bark color ( $p > 0.05$ ). There was also no significant correlation between lizard height and tree height ( $p > 0.05$ ) (Fig 2). There was a significant correlation between tree

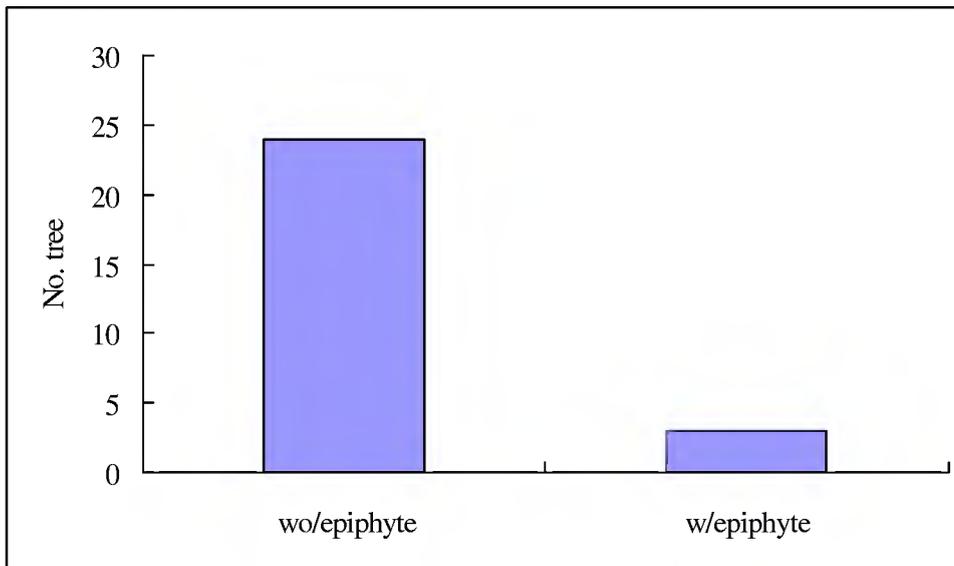


Fig 1 Frequency distribution of sampled trees with and without epiphytes.

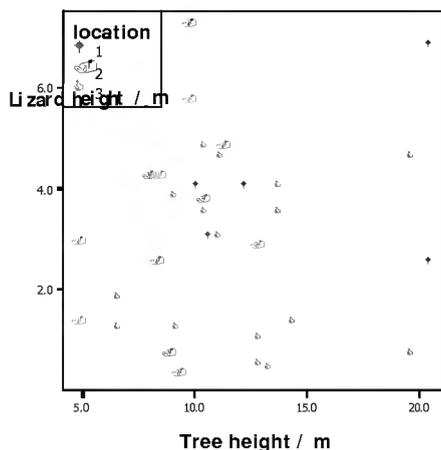


Fig 2 Correlation between lizard height and tree height ( $R=0.119$ ,  $P=0.511$ ).

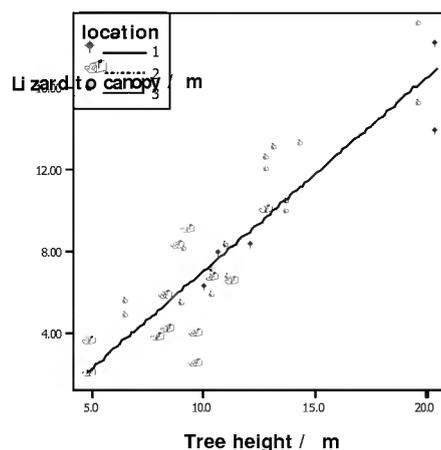


Fig 3 Correlation between distance from lizard to canopy and tree height ( $R=0.905$ ,  $P < 0.001$ )

height and the distance from lizard stationary to canopy ( $p < 0.05$ ) (Fig.3). Lizards were generally found on trees with dbh in the class range three to five (Fig 4). Within a nine meter radius, there were generally more than four trees (Fig 5). In the primary forest, plantation outside the classroom and on the other side of the river, five, four and one trees were selected, respectively, to confirm whether or not lizards avoided trunks with epiphytes. No lizards were found on these trunks.

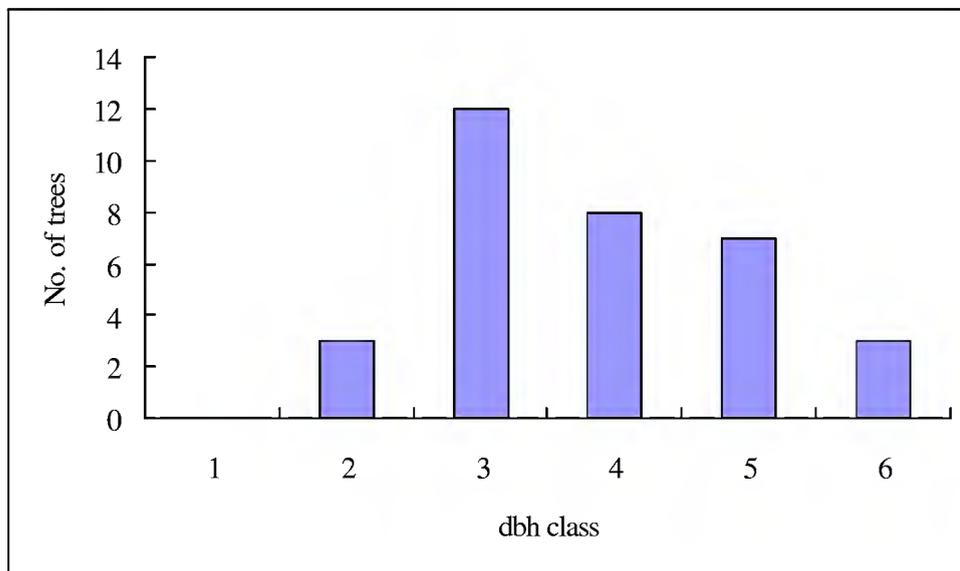


Fig 4 Frequency distribution of trees with lizards in the various class sizes - 1) <10 cm, 2) 10-20 cm, 3) 20-30 cm, 4) 30-40 cm, 5) 40-50 cm, 6) >50 cm.

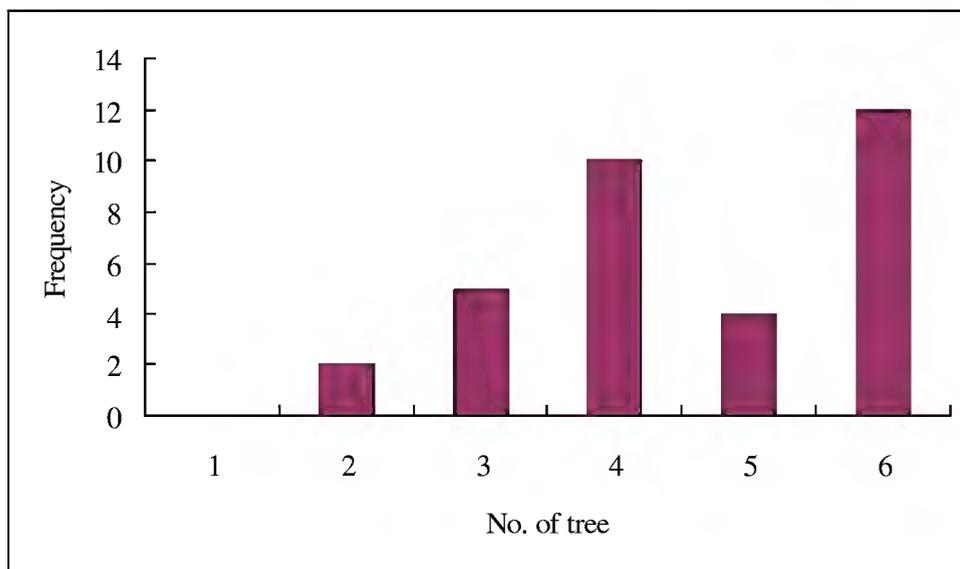


Fig 5 Frequency distribution of the number of trees observed within a nine meter radius of the trees with lizards.

## DISCUSSION

The number of lizards was actually lower in primary forest compared to the two other artificial forests. Greenstone (1984) showed that there was higher arthropod diversity in understory of primary forest and that the biomass was also larger. Mori and Hikida (1994) demonstrated that

ants were the major food resource for lizards. In the Central Amazonian rainforest, the ant biomass consisted 15 % of all biomass (Fittkau and Klinge 1973). Ants are distributed very widely and in great abundance (Pisarski 1978, Adis et al. 1984). The presence of great quantities of ants, and thus a food source, could explain the high gliding lizard abundance observed in non-primary forest habitats

We found that all the ants collected by Tanglefoot glue in our habitats belonged to the same morpho-species. Although there was no direct evidence that the gliding lizards preyed these ants, it indicates food resources were evenly distributed both qualitatively and quantitatively. This suggests the gliding lizards do not select microhabitats according to food availability.

There was no correlation between lizard height and tree height, but there was a highly significant correlation between tree height and distance from lizard to canopy. This indicates that regardless of the individual tree heights, lizards selected a similar relative position (about one third of tree height). The possible predators for gliding lizards are snakes and birds. Some snakes could move up the tree trunk from ground, while some birds would sit on branches for searching food. Hence, a position one-third of the way up the trunk might avoid predators from both ground and canopy.

There was no significant association between gliding lizards body color and tree trunk color. This is contrary to our prediction that the lizard body color should be similar to the tree trunk color. There may have been bias in the judgement of colour or possibly the fragmented coloration pattern of the lizards, is more important camouflage than color *per se*.

Within a nine meter radius of the tree with lizard, four to six trees would usually be observed. Hairston (1957) showed that gliding lizards do not glide to other trees to avoid predators, but to gain sunlight to increase the body temperature.

Lizards appear to prefer smooth trees without epiphyte. The lizard body color tends to be brown, similar to trunk bark color, while in stark contrast to the green leaf color. Thus, the presence of lizards on trunks with epiphytes would result in the lizard being an obvious target for predators. Gliding lizards preferred trees with a dbh larger than 20 cm. This might be because the more gradual curvature of trunks with greater dbh, minimizes the protrusion of the lizard from the bark, and thus reducing the conspicuousness to predators.

## CONCLUSIONS

Gliding lizards did not show any preference for different tree trunk colors, They preferred to rest on less shaded trees at about one third of the way up the trunk.

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*Independent projects*

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## **Effects of sunlight and temperature on microhabitat selection in tadpoles (*Rana* sp.): An experimental approach**

*Hazel Ty Consunji*

### **ABSTRACT**

Tadpoles in the later stages of development (with pronouncedly developed hind limbs and some with fore limbs) were seen near the water surface while younger tadpoles in deeper waters. Tadpoles were collected and brought back to the laboratory for experimentation on the effects of sunlight and temperature on the water depth preference of different stages. The tadpoles had a preference for deeper water across all developmental stages. The surfacing rate of younger tadpoles increased as the temperature was increased, while that of older tadpoles remained constant. Tadpoles undergoing metamorphosis undergo several physiological changes that prepare them for a terrestrial life. These changes could also help them adapt to different environmental conditions.

### **INTRODUCTION**

Habitat selection in aquatic animals is determined by environmental factors such as food availability, temperature, and the amount of dissolved oxygen. There is also the risk of predatory attack and competition for resources with other animals. Conditions also vary within a habitat creating microhabitats. The water temperature differs at different depths. It is higher near the surface, which is directly exposed to sunlight, and it gradually decreases as you go deeper. The amount of dissolved oxygen also tends to be higher near the surface since this is in direct contact with the air. Most aquatic plants and algae can also be found near the surface, where sunlight for photosynthesis is more readily available, and so oxygen from photosynthesis adds to the amount of dissolved oxygen in the water at this level. Cold water can hold more dissolved oxygen. Warm water gets saturated easily. This is a problem for the surface dwellers during the hot summer months when water temperature in the surface can reach as high as 35 °C.

Tadpoles undergo morphological and physiological changes before they completely metamorphose into a frog, which also involves behavioral changes from an aquatic life to a terrestrial life (Baglioni and Sparks 1963). The diet preference shifts from herbivory to omnivory and the ratio of aerial respiration to aquatic respiration (through gills and skin) increases. Tadpoles need to go to the surface more often as they grow older, because they need more oxygen (Burr and Just 1975; Feder and Morgan 1985).

Most species from the family Ranidae lay their eggs in the water and the tadpoles spend the rest of their lives in the same area, but are subject to different micro-environmental conditions within their habitat. This study aimed to investigate if tadpoles at different developmental stages prefer a particular water depth and whether sunlight and temperature, which vary with water depth, affect the water depth preference of tadpoles.

### **MATERIALS AND METHODS**

#### **Sample Collection**

The study was conducted along the Khao Chong river, approximately 1 km upstream from the center headquarters. The study site was an area where the river widened to about 7 m and the water flow rate was relatively slow. The vegetation at the study site was mostly tall grasses along the river bank and sparsely distributed aquatic plants and green algae on the surface near the bank. The site was an open area, receiving direct sunlight for most of the day. Tadpoles at different developmental stages were collected and brought back to the laboratory for experimentation. Collections were made at noon and the depth and temperature of water were recorded.

### Experimental Design

The tadpoles were kept in a tank in the laboratory. Several individuals were examined under the microscope for (morpho-) species identification using the teeth arrangement. The tadpoles were classified into three developmental stages for use in the experiments (Recently hatched tadpoles, Stage 3; tadpoles with hind limb buds, Stage 2; tadpoles with pronouncedly developed hind limbs, Stage 1) (Fig 1).

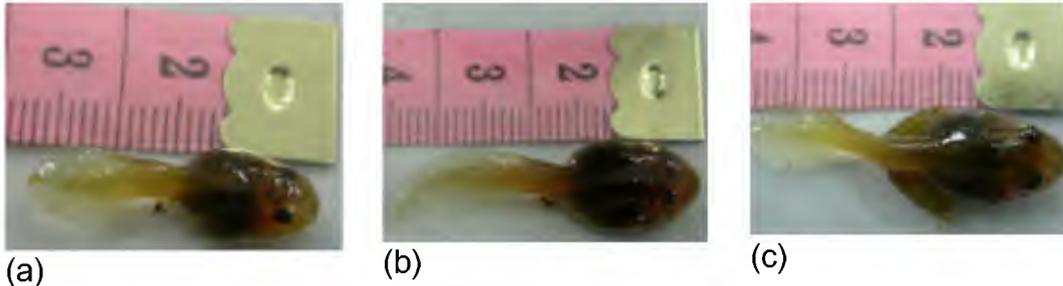


Fig 1 Developmental stages of tadpoles in this experiment (a) Stage 3, (b) Stage 2, and (c) Stage 1.

**Effect of sunlight:** A container was divided into three equal areas and filled with sand to make three different water depths (6 cm, 12 cm, and 24 cm). Ten individuals from each developmental stage were placed into the container and were allowed to acclimate for 10 mins under the sun. Then the number of tadpoles in each developmental stage was recorded at each water depth every 5 mins for 25 mins. No difference in temperature among depths was detected throughout the whole experiment. The water was disturbed to randomly distribute the tadpoles for the next phase of the experiment. The container was covered to block the sun and the tadpoles were allowed to acclimate for 10 mins. Then the lid was carefully lifted every 5 mins for 25 mins to count the number of tadpoles in each developmental stage at each water depth. Three replicates were conducted for each treatment.

**Effect of temperature:** three individuals from each developmental stage were collected from the tank. Water from the river was collected and lowered to a temperature of 25 °C by adding ice cubes. The tadpoles were then released into the container of water and were allowed to acclimate for 10 minutes. The number of times each tadpole from each developmental stage surfaced for air over 3 mins was recorded. Five replicates were conducted. The same procedure was repeated using water at a temperature of 30 °C.

### Data Analysis

In the water depth experiment the mean proportion of tadpoles for each developmental stage at each depth was calculate for each replicate of the experiment. This value was arcsin transformed to normalize the data. A full factorial model was used to analyze data from both experimental setups (Experiment 1: sunlight treatment, water depth, and developmental stage; experiment 2: temperature and developmental stage).

## RESULTS

Tadpoles from all three developmental stages in both treatments spent more time on the lowest level (deepest part) of the container (depth effect  $p < 0.0001$ ). However, it is worthwhile mentioning that the interacting effect of level x stages x sunlight treatment was almost significant ( $p < 0.0659$ , Table 1).

Table 1 Effects test from a full factorial model for Experiment 1: Effect of sunlight, water depth, and developmental stage (C. Total  $p < 0.0001$ ).

Source	DF	Sum of Squares	F Ratio	Prob > F
Sunlight treatment	1	0.58074	0.6672	0.4194
Water depth	2	177.65481	102.0570	<.0001
Developmental stage	2	1.16593	0.6698	0.5181
treatment*depth	2	4.53481	2.6051	0.0878
treatment*stage	2	1.16593	0.6698	0.5181
depth*stage	4	3.53185	1.0145	0.4129
treatment*depth*stage	4	8.43852	2.4238	0.0659

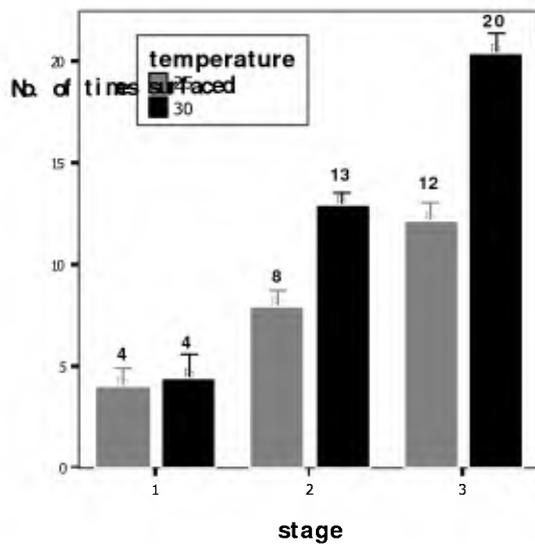


Fig 2 Surfacing rate against temperature across different developmental stages in *Rana* sp. tadpoles

Table 2 Effects table for a full factorial model of experiment 2: Temperature and developmental stage (C. Total < 0.0001)

Source	DF	Sum of Squares	F Ratio	Prob > F
Temperature	1	149.63333	24.2649	<.0001
Developmental stage	2	756.60000	61.3459	<.0001
Temperature*stage	2	84.06667	6.8162	0.0045

The temperature has a significant effect on the tadpoles from each stage and across stages (Table 2). The number of times the tadpoles surfaced increased as the temperature increased, and the proportional increase in surfacing rate was highest for the youngest tadpoles (Fig 2). The results also show that the younger tadpoles surfaced much more often than the older tadpoles.

## DISCUSSION

Ultraviolet light radiation from the sun has detrimental effects on tadpole development. Water level and light intensity are correlated. Deeper water receives less sunlight and UV radiation. Thus, tadpoles may prefer deeper levels because of the lower light intensity and the less exposure to UV radiation.

Oxygen requirements increase as tadpoles mature, as the gills are being replaced by lungs. One would, therefore, expect older tadpoles to surface more often than the younger tadpoles. However, my results show that younger tadpoles surfaced more often than the older tadpoles. Moreover, it is interesting to note that the rate of respiration for older tadpoles did not change as the temperature increased. This could be because the older tadpoles had a more stable metabolism, through their lower surface area to volume ratio, and could use their oxygen more efficiently. A stable and efficient metabolism would be helpful in the conservation of energy, and permit the allocation of energy for different purposes, such as growth and development. Staying in shallower waters could further reduce the need to surface for air.

Deeper waters have a relatively low temperature and higher dissolved oxygen concentration. They also provide a certain level of UV protection. However, food supply in deeper waters might not be as abundant in shallow waters, especially for older tadpoles that are shifting to a diet of small insects and detritus. Thus, other factors may influence the microhabitat selection of tadpoles.

In the natural habitat where temperature and other factors can have either contradictory or complimentary effects, it is difficult to isolate and determine the direct effect of a single factor. As tadpoles develop, they also undergo physiological changes that may help them adapt to a new set of micro-environmental conditions. There are few published studies on the physiological changes that tadpoles undergo during development but it has obvious relevance to their microhabitat selection.

## CONCLUSIONS

My experiments found that tadpoles selected deeper water regardless of the level of incident sunlight or developmental stage, and that temperature had a stronger effect on the surfacing (respiration) rate of small tadpoles than on older tadpoles.

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## In the news



STRI's Center for Tropical Forest Science-Arnold Arboretum (CTFS-AA) Asia program's annual International Field Biology Course was opened by Surapon Wichaidit, deputy governor of Trang Province at Khao Chong in peninsular Thailand on Wed, June 16. Twenty one students will receive instruction in plant and animal taxonomy, population biology, soil science, plant-animal interactions, molecular ecology and evolutionary biology. Twenty specialists, including CTFS and STRI researchers, will serve as instructors. The course, organized by STRI postdoctoral fellow Rhet D. Harrison, is hosted by National Parks,

Wildlife & Plant Conservation Department Thailand. The program includes field trips to mangrove forests and swamp forests near Khao Chong and an extended trip to dry deciduous forests in the north of Thailand.

El Curso Internacional de Biología de Campo del programa de Asia del Centro de Ciencias Forestales del Trópico de STRI-Arnold Arboretum (CTFS-AA) fue inaugurado por Surapon Wichaidit, vice-gobernador de la Provincia de Trang en Khao Chong en Tailandia peninsular el miércoles 16 de junio. Veintiún estudiantes recibirán clases sobre taxonomía de plantas y

animales, biología de poblaciones, ciencias de suelos, interacciones entre plantas y animales, ecología molecular y biología evolutiva. Veinte especialistas incluyendo investigadores del CTFS y STRI servirán como instructores. El curso, organizado por el becario postdoctoral de STRI, Rhet D. Harrison, se lleva a cabo en el Departamento de Parques Nacionales, Vida Silvestre y Conservación Vegetal de Tailandia. El programa incluye visitas al campo a bosques de manglar, bosques pantanosos cerca de Khao Chong, así como un viaje a los bosques secos deciduos al norte de Tailandia,

## Great tropical hospitality!

If you go to Culebra, it is very probable that this male Yellow ("Mangrove") Warbler would welcome you at the entrance gate, taking a riding with you on your rear view mirror!

Si usted va a Culebra, es muy probable que este canario manglarero lo reciba en la entrada, y pasee con usted en su espejo retrovisor!



### More publications

Villanueva-G., Roger, Roubik, David Ward, and Colli Ucan, Wilbero. 2005. "Extinction of *Melipona beccarii* traditional beekeeping in the Yucatán peninsula." *Bee World* 86(2): 35-41.

### STRI in the news

Las Perlas, futuro incierto. At <http://www.albatrosmedia.net/web/>

### July birthdays

Enith Rojas	2
Mark Brady	2
Andres Hernández	3
Orelis Arosemena	4
Nikka Teixeira	6
Eduardo Ortega	6
Renier Vargas	8
Dora Justo	10
Rafino González	10
Meylin Hernández	12
Soreno Campos	12
Ruben D. Hernández	12
Phyllis Coley	13
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Aldtel Osés	19
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